Machine Shop Practice: A Manual for Apprentices and Journeyman Machinists, and for Use in Trade, Industrial and Technical Schools

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[William J. Kaup]

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PREFACE

In preparing this text the author has endeavored to present the fundamentals of Machine Shop Practice rather than to produce a complete or advanced treatise. Above all, he has desired to lead the pupil in the shop to *think* and not merely to do. For this reason, the *why* of each step or operation is emphasized quite as much as the how. If the apprentice or the trade student can once be imbued with an attitude of thoughtfulness and investigation in connection with his work, his future progress toward skill and efficiency may be regarded as assured.

The material is drawn mainly from mimeographed notes which were tried out for over twelve years in the shops of the School of Science and Technology, Pratt Institute. With the desire, however, to meet more closely the needs of the increasing number of secondary technical and industrial schools offering machine shop instruction, the original text in which these notes were published has been carefully revised by Mr. J. A. Chamberlain, Supervisor of Manual Training in the schools of Washington, D. C. It is believed that the value of the book as a practical manual for apprentices and journeyman machinists has in no respect been lessened in this revision, while at the same time the order of treatment and the time demanded for the completion of the work laid down have been brought to a closer agreement with the conditions under which machine work is taught in the secondary school shop.

EDITOR'S NOTE

Not the least of the essentials for a shop treatise which is to be used as a school text is that it shall be brief without becoming a mere collection of formulæ and rule-of-thumb methods. It must be usable under the conditions that control the school roster. At the same time, it should develop and inspire the pupil and not merely supply him with information.

This revision of "Machine Shop Practice" is added to the *Wiley Technical Series* in the belief that it meets most admirably all of the above requirements. The author's training as an apprentice and shop superintendent and his wide experience later as an engineer have all been drawn upon in the preparation of the manuscript. Mr. Chamberlain has assisted in giving to the text an arrangement and manner of presentation suited to the needs of the school shop. The Chapters on "Tool Making," which appeared in the earlier edition, are here omitted and this subject will be presented as a companion volume soon to appear in the *Technical Series.*

The Editor.

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MACHINE SHOP PRACTICE

CHAPTER I

VISE WORK

Chipping

The flat cold chisel; its shape. Economic angle for the chisel. Value and correct use of the facet as a guide. Straight versus curved edge. Grinding the chisel. The cape chisel. Other forms. Hammers; their forms and weights. The vise. Chipping.

WHILE it is true that in modern shop practice much of the work that was formerly done in the vise by hammer, chisel, and file is now machined, yet a knowledge of vise work and the hand tools is still necessary to the first-class mechanic, and this knowledge very often proves the means whereby he succeeds.

In discussing elementary steps in the machine shop, it is assumed that all are beginners and unacquainted with tools and their uses; but should there be those who have had some little experience in different shops (while not in direct application of the several principles), it will also prove valuable for such to learn, not only the uses of the tools, but the reasons underlying their construction.

1. Chisels. Our first lesson is to be chipping, and we have to do with cold chisels. To know the proper angle of the facets or edges is important, and the relation the facets bear to the proper holding and use of the chisel is more so.

shape, **diamond point.** It is used by die makers, for corner chippings, for correcting errors while drilling holes, etc.

Fig. 10 is still another form of chisel which is more common among tool makers than machinists. It is used for

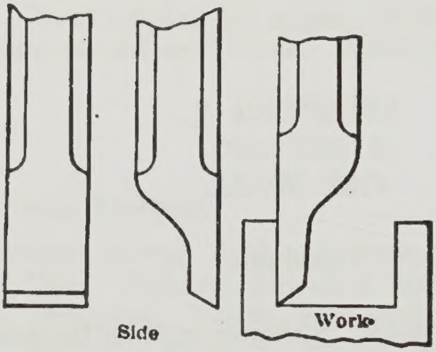


FIG. 10.—Chisel for Chipping Square Holes.

squaring the sides of dies and punches and for chipping square holes of different depths.

2. Hammers. The three ordinary forms of the hammer are recognized by the different shapes of the top or peen. In Fig. 11 the left hand-cut shows a flat peen which is

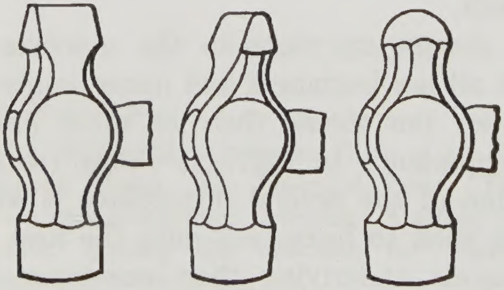


FIG. 11.

parallel to the handle; this is called a **straight-peen hammer.** The center cut shows a flat peen at right angles to the length of the handle; this is a **cross-peen hammer.** The right-hand cut shows **a ball-peen hammer.** The peen is used

chalk or bluestone solution; prick punch; 1-lb. hammer (ball peen); 6″ scale; calipers (outside); small hammer for outline work.

See that the prick punch is sharp.

Determine the construction of the vise. Be sure the vise jaws are parallel. Do not use too much force in screwing up the vise; if the jaws fail to hold, look for the reason eleswhere; you will invariably find that the work itself is not parallel, as all castings have a certain amount of taper or draft. Small pieces of cardboard will prove efficient when placed between the work and the vise jaws.

Form habits of cleanliness and order; these are two essentials of a good mechanic. Keep the work bench and vise clean and do not scatter the tools promiscuously over the bench.

The steps we are to follow, with pertinent suggestions, may be detailed thus:

Bevel Block. Flat Chisel. 1. Read the drawing carefully preparatory to laying out the work. A few minutes spent in careful study before starting very often avoids spoiled work.

2. Chalk the surface of the block where lines are to be drawn. By rubbing the finger over the chalked part, a better effect is obtained. In marking the outline with the prick punch, use very light blows to permit the absolute removal of all marks after finishing. Lay out one edge of the block first, for practice chipping.

3. See that the chisel is sharp and ground to proper angles, also that the hammer handle is tight in the eye.

4. Place the work in the vise so you will chip toward the dead or stationary jaw of the vise always. This part of the vise gives the greatest resistance to the hammer blows; see Fig. 13. Hold the work at such an angle that both lines limiting the cut to be made are in the field of vision.

5. Start with a light chip and light blow; watch only the cutting edge of chisel—not the top. Hold the hammer at the extreme end of the handle. The hammer should be thrown back vertically over the shoulder with wrist and elbow movement only. Do not hold the chisel too tightly; by doing so you tighten the cords in the wrist

liable to break out. Avoid this by working from both edges toward the center.

4. Chipping Wrought Iron. We have thus far dealt with cast iron only, which is porous and brittle, and crystalline. Wrought metal is dense and fibrous; hence it is tough and the chip will curl instead of break off. More force must be applied; that is, heavier blows must be struck to cut the same size chip on wrought metal as on cast metal. In chipping wrought metal, lubricate the end of the chisel by occasionally dipping it into a piece of oil-soaked waste, placed conveniently on the end of the vise.

QUESTIONS

1. What is the best angle for a cold chisel?
2. What are the objections to a sharper angle?
3. What are the objections to a more blunt angle?
4. On a grindstone with grooves, how can a cold chisel be sharpened flat?
5. About how wide should the facets of a cold chisel be?
6. What are the objections to a cold chisel sharpened to 70° but with a curved edge?
7. About what weight of hammer should be used in chipping?
8. Where should the handle be grasped?
9. What arm joints should mainly be used in moving the hammer?
10. Should the hammer head be thrown back over the shoulder at each stroke? Why?
11. Where and how should the chisel be grasped?
12. Toward which jaw of the vise should chipping always be directed? Why?
13. Should chipping be continued toward and up to the end of a block?
14. If the work slips in the vise, how can the slipping be avoided, otherwise than by tightening the vise? (Three ways.)
15. Should a cold chisel ever be lubricated? If so, when and how?
16. What chisels other than flat chisels are in common use?
17. For what kinds of work is each adapted?
18. How is the burring of the sides of a chisel-cut groove prevented?

inch) unless the length of the file is also given. That is, the pitch of a 12″ bastard file is not the same as that of an 8″ bastard; the pitch is proportioned to the length.

Files are further described by terms indicating their

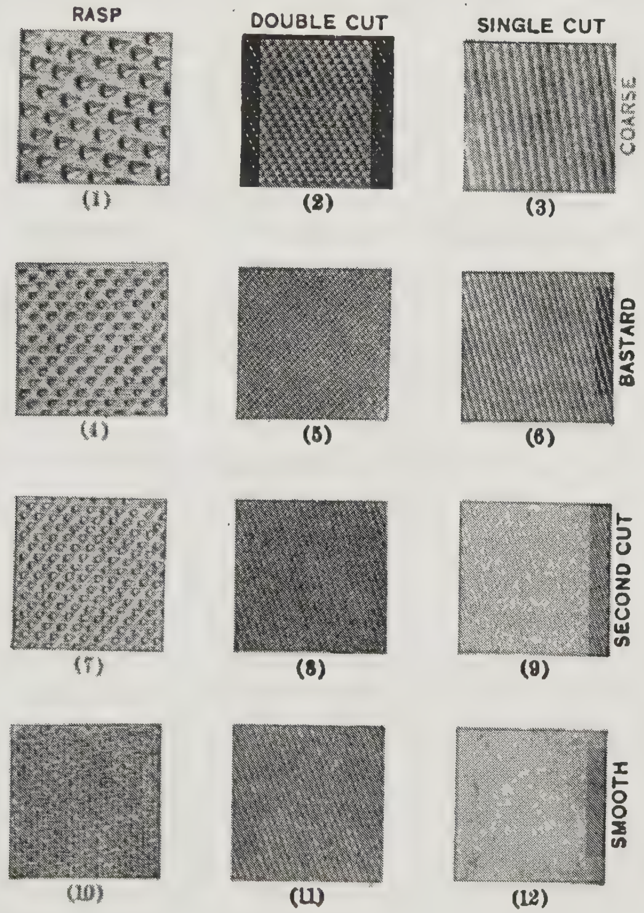


Fig. 15.

shape. The most common are—the flat file, the half-round, the round, the square, and the triangular or three-cornered. All these are "full-tapered" files, that is, the sides and edges are about parallel for approximately a third of the length, after which all dimensions of the cross-sections diminish toward the point.

The term "safe edge" means that one edge is smooth, without teeth.

Fig. 13.

The sharp drawn-out point upon which the handle is fitted is the *tang*. The part of the file nearest the tang is the *heel.*

In the earlier days of files, they were made by hand and the teeth were more or less irregular, depending upon the skill of the mechanic who cut them. Some of the teeth were higher than others, thus giving fewer contact points; this proved desirable, but the cost of hand-made files was necessarily great. Now, machines are used whereby the cuts of the teeth are increased or decreased, giving the same effect as the earlier hand-cut files. These are called **increment-cut files.**

The life of a file depends largely upon the metals filed. Tool steel approaches the hardness of the file teeth, consequently the life of the file will be shorter when used on it than on the softer metals. Avoid using good files on the scale of castings or forgings, for it is very hard. Scale should be removed with the edge of the file only, no matter whether the file is old or new.

6. Selecting the File to be Used. First in order is the selection of a file to do the required work. In making the selection, the kind of metal must be known, and whether a narrow or broad surface is to be filed. Cast metals are harder to cut with files than wrought metals. Consequently, on the former we use new files and, on broad surfaces where much metal is to be removed, we use coarse or rough-cut files. After these files are worn beyond the economic point for cast metals, they will be found still serviceable for wrought metals.

Always avoid a file that is very thin, as it bends readily under usage, and will give a rounding surface. Much time

commonly made by beginners in fitting handles, and that is the drawing of the temper in the heel of a new file while heating it. When it is necessary to heat the new file, dip a piece of cotton waste into water and wrap it around the heel of the file to keep the temper from being drawn.

The reason for selecting a file with convex sides as in Fig. 19, is this: The greater the number of teeth bearing on the work, the greater must be the pressure applied to make the file bite or cut. With all the teeth in contact great pressure would be required, whereas, if only one-quarter have contact, Fig. 20, the pressure would be re-

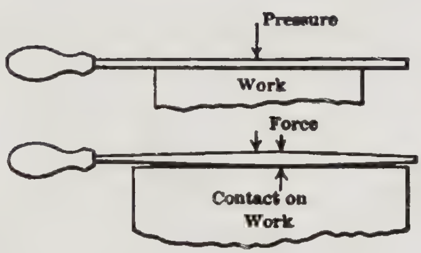


FIG. 20.

duced three-quarters. Files are made with convex sides purposely, therefore, but sometimes they warp in hardening, and all the convexity is on one side, while the other side is hollow. In beginning work, sight along the edge of the file and use the convex side.

It is plain that the longer the bearing along the work surface, the more easily can the file be balanced. This balancing is the first step the beginner should acquire.

We now know four important things: First, new files are to be used for cast metals. Second, coarse files are used for removing much stock from broad surfaces. Third, the value of the convexity of the file. Fourth, the importance of balancing the file.

your file marks, as in Fig. 22. This is an economical method when much metal is to be removed, but is permitted with only the coarse files. The reason it is economical is that the file makes grooves along the surface, hence, by changing the direction of the stroke, the tops of the ridges left by the file in the former cut are removed. It is preferred, however, to avoid the crossing, even with rough files, because it takes the beginner longer to learn straight, flat filing, and for this reason: In filing from right to left, Fig. 23, the right arm is following in a line close to the

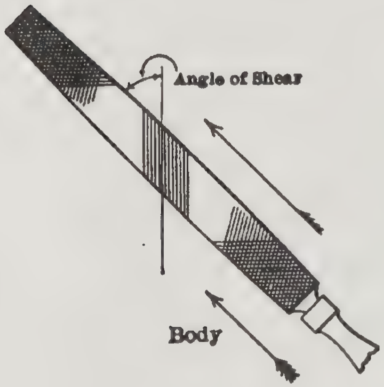


FIG. 23.

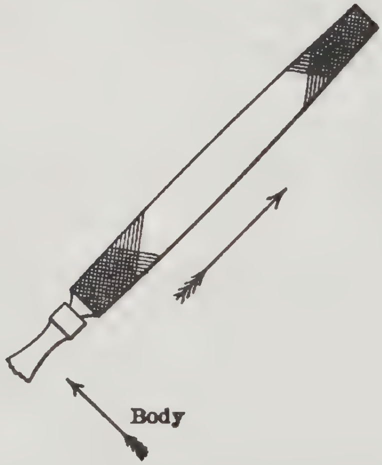


FIG. 24.

body and with short leverage, while in filing from left to right, as in Fig. 24, the arm leverage is extended, which lessens the student's control of the file.

Stand naturally at the vise. Make a full stroke forward, keeping the right foot well behind the left, and balance on the left when making the stroke. Avoid short, jerky strokes; accustom yourself to the long, easy strokes, not applying much pressure until you have accustomed yourself to the proper return stroke. The pressure is always applied on the forward stroke and relieved on the return. The file is always returned resting on the work, as the file balance is thereby preserved. The file must be firmly held, because the object is to make the stroke a straight and level one.

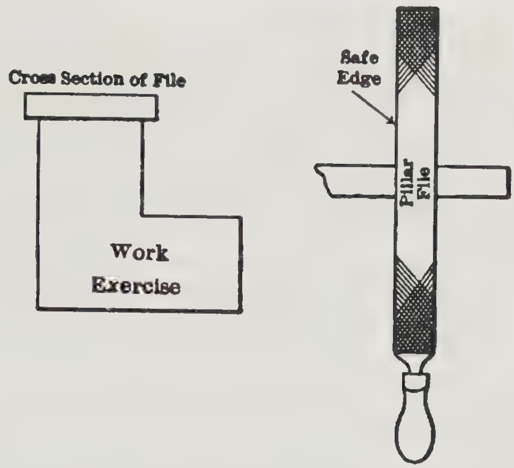
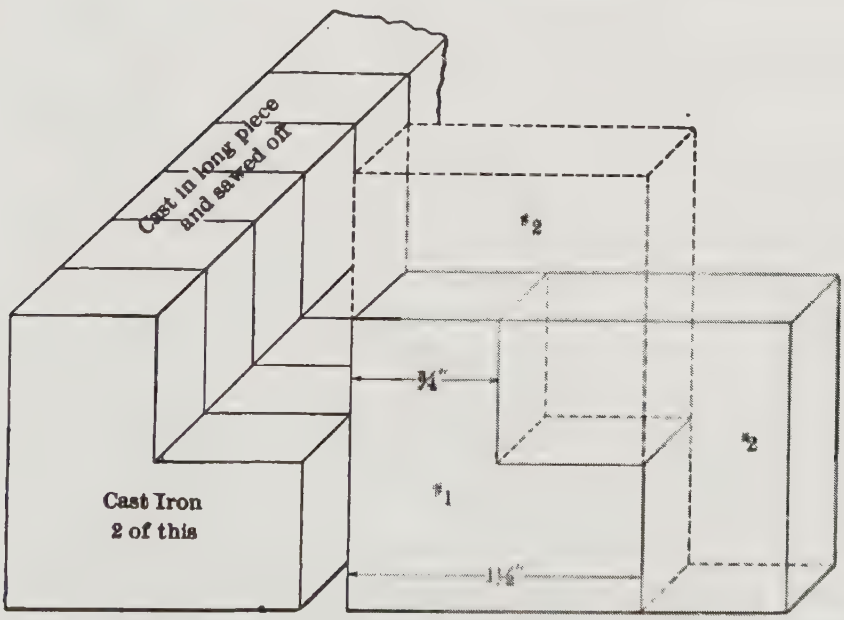


Fig. 26.—Filing an inside Corner.



3d Step

Interchangeable
Filing

Fig. 28. Fig. 27.

Corner Filing Pieces.

outside edges of the inside gauge block are first squared and made parallel. The outside or plug gauge is then filed, using the calipers as accurately as possible. Finally the slot is filed, the calipers being used to size the legs and make them parallel; this should leave the sides of the slot parallel also. The plug should be used for sizing the slot. It should be turned end for end in the slot and also at right angles to the plane of the block, from time to time, to check the parallelism; if it fits in the top and bottom of the slot and not in the middle, it is clear that the work is rounding; that the student is not holding his file flat, but is rocking it.

Exercise 4—Rack-tooth Template

In the exercise, Fig. 30, the object is to teach accurate filing and also to bring out a vital point in the simplest possible form, viz., where the error in the work actually is.

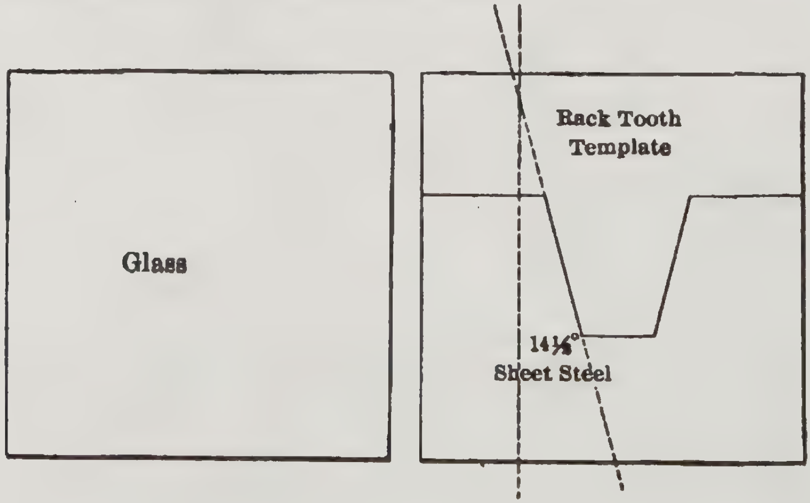


Fig. 30.

To remove metal in the wrong place spells failure, as the workman discovered who filed only the spots on the valve seat that did not touch, because he already had a good bearing on those spots that did touch!

The rack-tooth template, to be of any value, must have like angles on the sides of the tooth. By repeated reversing of the

hammer and chisel, not because the manufacturing world to-day demands a product from these tools, but as the simplest and quickest method of impressing the student with the value of the cutting angle and with the principle that the lighter the chip the lighter the blow, or that the force applied should approximately equal the resistance of the metal being cut.

Second Step. The introduction of other chisels for purely economic reasons; the best way to remove metal on surfaces wider than the flat chisel in order to keep the whole surface more nearly in a plane; the more regular the chipped surface, the better the filing which follows can be accomplished.

Third Step. The introduction of different files, and methods of using them, and the training of the sense of touch.

Fourth Step. Checking the inaccuracy of both eye and touch by a positive method. (Plug gauge.)

Fifth Step. The making of a working tool, and in making it to teach the method of exactly locating an error. (Template.)

The proficiency of any course depends entirely upon how closely the details are followed, and those who are willing to give these exercises a conscientious trial will satisfy themselves that the course outlined is based on good practice.

The workman should grind his own chisels, under competent direction, and, during the elementary work, lathe tools which have not been hardened should be given as filing exercises, so that proper angles, rakes and clearances can be studied before advancing to machine tools.

The lathe tools also will furnish elementary use of the gas furnace in hardening and tempering, at a period when loss by failures is reduced to a minimum.

Never rub the hand or finger over the work if filing cast metals, as the hand is coated with oil and it makes the surface hard to file.

Filed surfaces should be protected in the vise by either soft copper clamps or leather jaws.

CHAPTER III

SCRAPING

Its value in the field of machine construction. Shapes of scrapers and their various uses in the trade. How plane surfaces are developed. Theory underlying it.

10. Scrapers and their Proper Uses. Our next step is to take the filed surfaces down to a more accurate finish, and to do this we employ hand tools called **scrapers.**

The first question that naturally arises in the mind of the student or beginner is, "Why is it necessary to scrape a bearing surface when the work seemingly comes from the shaper or planer with a true surface?" Does it come from the machine true? All work that requires clamping or binding in place on a machine, has thereby certain pressure brought upon it, which tends to distort its shape, and, no matter how delicately clamped, it will be affected to some degree. No matter how solidly the work may be bedded on the platen of the machine, nor how well it may be supported against compression by the clamps, it will spring, although the deflection may be almost imperceptible. Another reason is found in the very nature of castings, which, no matter what the metal is, change their shape after the scale is removed.

The use of scrapers requires a delicacy of touch we have not quite attained in our use of files, but we first study the tools, as in our earlier lessons, to learn their natures before attempting their use. Fig. 32 gives one style of scraper, double-end type, made from $\frac{7}{16}''$ octagonal steel, flattened on both ends and hardened as hard as fire and water will make it. These should be ground straight along the

Only high-grade steel, whether in new stock or in old files, should be used for scrapers. Any saving here is more than offset by the time lost in frequent sharpenings.

On account of the great hardness of the scraper, special care is necessary to avoid drawing the temper when grinding.

11. Scraping Surface Plates. The first essential step in scraping a flat plate is to try the plate with straightedges to see if there is any wind or twist. This is done by placing the straightedges on both edges of the plate and sighting over them. The straightedges being considerably longer than the plate, the error will be so multiplied as to be easily seen. If there is much twist, file the high corners, as that is the most economical way.

Fig. 36.

Fig. 37.

Fig. 38.

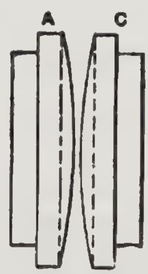


Fig. 39.

To scrape a pair of surface plates accurately a third plate must be used, as it is possible to scrape two surfaces together and still have the surfaces out of true, as in Fig. 36. We might take 3 plates and mark them A, B, and C. Try A and B together, as in Fig. 37. Then B and C, as in Fig. 38, after which any error will be readily discovered by trying A and C together, Fig. 39. That is, A and B may be so scraped as to fit together, but with curved surfaces instead of plane surfaces. Plate C may be similarly scraped to a fit with B, without being true, but the errors are clearly evident when A and C are tried together. The reason why three plates are necessary, therefore, is that one acts as a gauge to the other two.

surface, we first scrape in one direction, then in another, between the parts already scraped, which gives the appearance shown in Fig. 40.

There are certain places where scraping is used to a great extent: for instance, on the ways of a lathe, or the ram of a shaper. In these cases the parts themselves are used together, one bearing being worked into the other.

Do not get the idea that scraping is merely to help the appearance of work. It is sometimes employed for that purpose, but its real value is in obtaining more uniformly fitting surfaces which bear, and *wear*, upon each other. As the area of contact is increased the wear is much slower. It may come to the student as a new and surprising thought that, when it is necessary to obtain the finest, most accurate surface, we must look to the simple tool and the skilled hand rather than to the machine.

QUESTIONS

1. What is the value of scraping?
2. How should scrapers be ground?
3. What is the result if they are not properly ground?
4. How are the bearing points determined?
5. What materials are commonly used to show contact points?
6. What is the disadvantage of using red lead or Prussian blue too thickly?
7. Why is it necessary to use three plates?
8. What is the advantage of changing the direction of the scraping stroke in scraping a surface?
9. What is the advantage of a master plate?

to be turned; the fingers of the hand should grasp the tool on the bottom side and the thumb should hold the tool down on top.

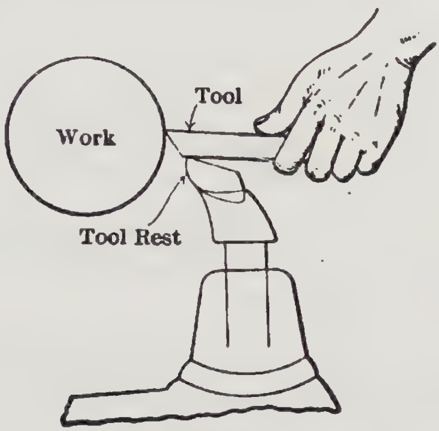
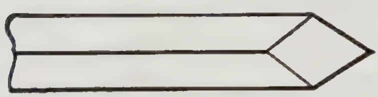


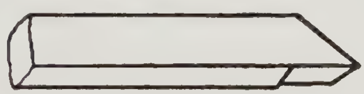
FIG. 41.

A small universal chuck is a requisite of the machine, and should be used without strain; the work should be centered for the purpose of using the tail center as an end support. Herein lies an element of danger; the work, traveling at a high rate of speed, generates friction on the center, and quickly dries the lubrication, hence a thin oil



Turning and Finishing Tool.

FIG. 42.

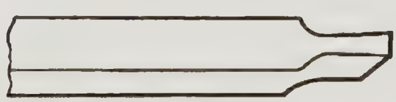


Cutting-off Corner Tool.

FIG. 43.

Turning Tool.

FIG. 44.



Cutting-off Tool, Right and Left.

FIG. 45.

is not good; soap or tallow will prove more efficient and lasting because, being heavy, it requires a higher degree of heat to melt them.

CHAPTER V

MATERIALS OF CONSTRUCTION

Different kinds used and why. Cast iron and its application to modern construction. Bronze and its function. Crucible steel and its importance. Theory of design.

IT is essential that the mechanic who operates a machine, as well as the student who is learning, should be thoroughly familiar, not only with the different kinds of material used in its construction, but also with the reasons for selecting a particular material for the given part

13. Locating the Wear in a Machine. The experienced machine designer spends his best effort on the breaking-down point of the machine to the end that it be so located and the parts so arranged that they can be replaced at least cost in money and time. All machinery that is subjected to high speeds, therefore, is arranged to have the preponderance of wear take place in certain parts, as, for illustration, the bearings of the machine. This necessitates the use of a softer metal for the bearings than for the shaft or spindle which runs in them.

For rotating machinery two like metals are seldom used in moving contact; not because they will not wear well, but, chiefly, because too much of the wear would be distributed on the shaft or spindle instead of being confined mostly to the bearings. Cast iron and cast iron can be used to run together efficiently if the area of the wearing surfaces is large enough to reduce the frictional wear to a minimum, but the size of the shaft and the whole general design of the machine would have to be on a very large scale. There are machines on the market to-day with cast-iron

We do know that the mainspindle is designed to carry a tool-steel center, a harder material than the spindle itself, because the centers must withstand all of the crushing force of the whole load. They are also fitted to a taper. Why? Because they are more readily fitted into place, are easily removed, and, more important than all else, accuracy and alignment are always maintained, for, as the centers wear from constant taking out and putting back, they will go in farther, but the centralization is not affected.

15. Shafting. Cold-rolled steel shafting would in no sense be classed with the materials of construction; its efficiency lies in the field for which it was specially designed, where it can be used without disturbing its outside shell, for line shafting and power distribution. When turned down, its efficiency is lost, and, further, due to the unequal strain of cold rolling, it will not remain straight.

The materials of construction are so selected that the machine will have the maximum life with the minimum cost of up-keep.

QUESTIONS

1. What is the general theory of machine design?

2. What metals are most commonly used in machine construction?

3. For what parts is cast-iron chiefly used? Why?

4. For what parts is steel chiefly used? Why is it particularly adapted to such use?

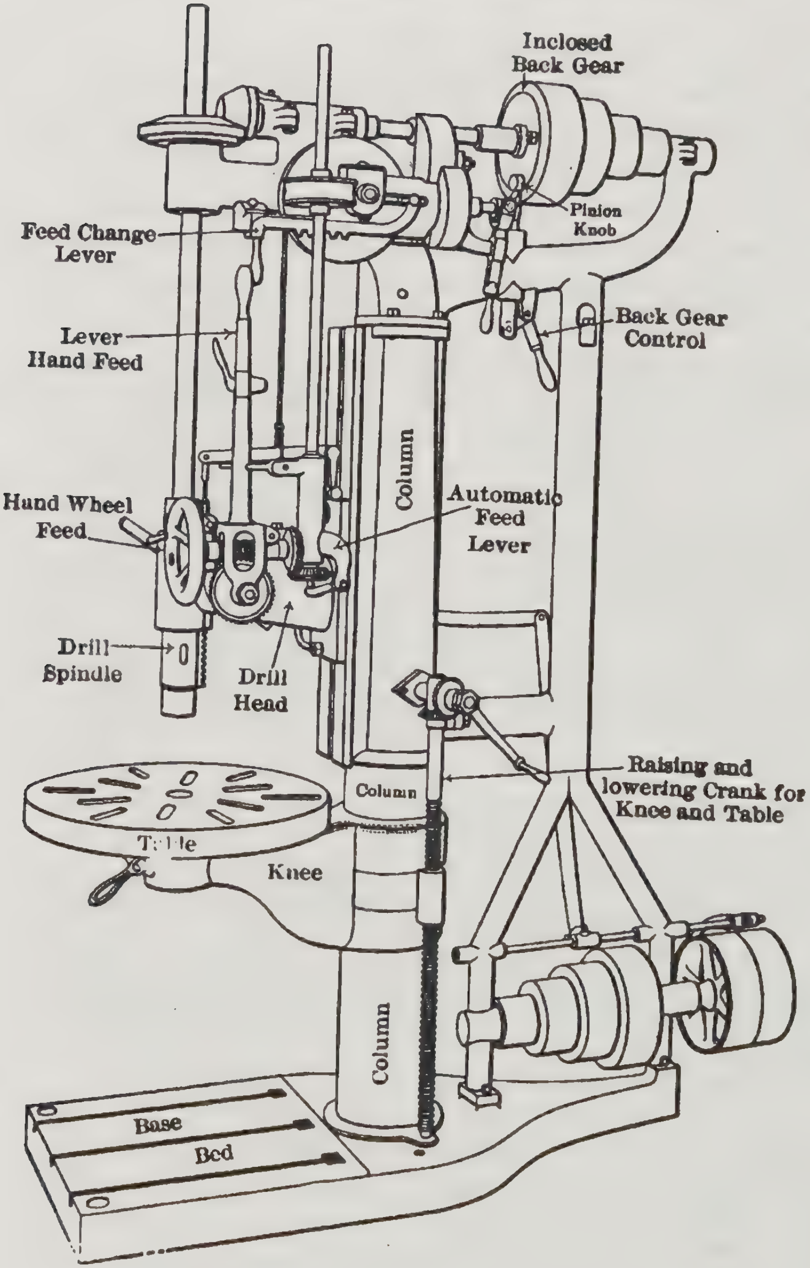


Fig. 46.—W. F. & J. Barnes Drill Press.

Build up of machine, showing relation of parts to each other.

Bed (C. I.)	Column	Elevation screw			
		Knee	Table	Work	
		Ways	Sliding head	Feed mechanism	
				Drill spindle	Drill
		Main spindle for driving			
	Transmission counter shaft (C. I.)				

name indicates, has more than one drill spindle and is capable of drilling more than one hole at a time. Drills of this type, of from two to six spindles, are frequently listed.

17. Twist Drills. By far the most important boring tool in any shop is the twist drill. Formerly this drill was made by twisting a piece of flat stock, which accounts for the name. Now the drill is made from a round bar of steel by cutting helical grooves in it.

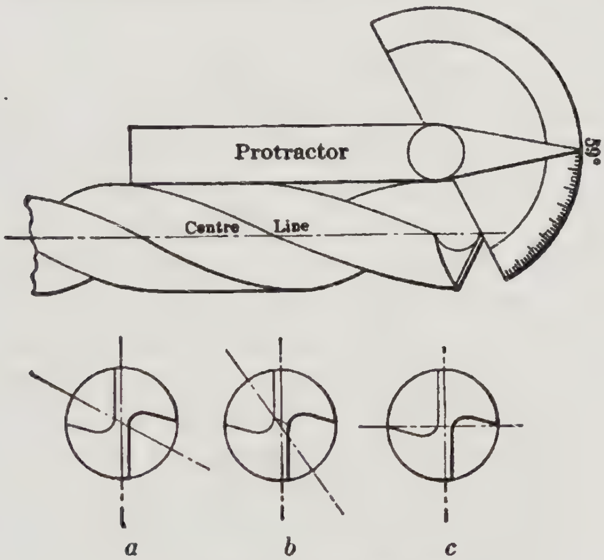


Fig. 48.—Lip Clearance.

The ordinary twist drill is described as having a *body*, a *shank* and a *tang*. Drills are made either "straight" or "taper" shank.

18. Essentials of a Good Drill. Experience has proven that with no other type of boring tool have there been so many disappointing results, hence the student should early learn the essentials of a good drill. The modern, well-made drill has "longitudinal" clearance; that is, it is ground slightly tapering down from point to shank. It also has "body" clearance; this means that the drill is ground off slightly toward the back of the groove. In Fig. 48 *c*, the

diameter indicated by the horizontal line is less than that shown by the vertical line, which is parallel to the "lips." These clearances are to avoid friction, and consequent heating, in the hole.

It must be patent, also, that three things are important respecting the lips or cutting edges of a drill; first, they must make equal angles with the longitudinal axis of the drill; second, they should be properly cleared or backed off; and third, they should be of equal length.

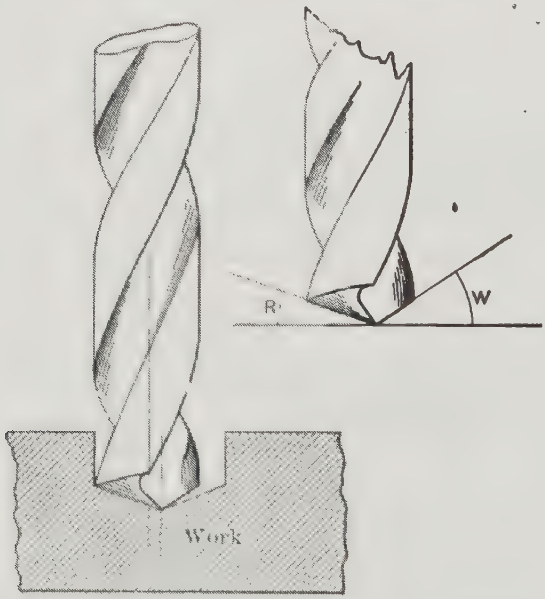


FIG. 49.—Result of Improper Grinding.

The angle for iron and steel is from 59° to 60°, and for brass from 75° to 76°,—a greater angle in the latter case because of the tendency of the drill to hook into the softer metal, especially when the drill is about to break through the work. The angle of the point is a sure indication of the lip clearance, as illustrated at *a*, *b*, *c*, in Fig. 48. Too much clearance, as shown by *b*, will produce irregularly shaped holes.

Fig. 49 indicates the results of improper grinding. One

lip is much longer than the other, hence the two edges are at different cutting angles and only one lip cuts, making it impossible to drill holes anywhere near the correct size.

Another thing that gives considerable trouble is carelessness about the point of the drill. It must be sharp, or else, no matter how keen the outer parts of the cutting lip may be, the drill will not work without considerable pressure, which in extreme cases tends to crush the drill.

19. Accuracy in Drilling. A very important detail to observe in drilling is the starting of the cut. If the drill runs out of center before it begins to cut the full diameter of the hole, it should be drawn over to the center by gouge-chiseling that side of the conical hole which is nearest the center. If, from the same center used in laying out the hole, a circle is scribed somewhat smaller than the desired hole, it will serve to indicate more closely whether the drill is following the correct course. This is more important in holes that are to be rebored, for it is desirable that equal metal should be left on all sides for the next boring bar or cutter. In every instance where accurate drilling is desired, it is advisable to drill a small hole first, as in Fig. 50, so the large drill will hold the center more accurately. This also relieves the point of the large drill from acting as a pivot, and a hole of more exact diameter is obtained.

Fig. 51 shows a "farmer" or straightway drill, used successfully on cored holes. This is also available as a common bit for lathe work, by first boring the work to a size just deep enough for the drill to enter, and then by using the latter, feeding with the tailstock screw.

Another small thing that defeats good work,—and the chance for promotion of many mechanics—is shown in the upper left-hand corner of the same illustration; a little speck of dirt or a small chip came between the drill shank and the socket and made a depression in the drill shank every time the latter was driven up into the socket, until the shank had a pock-marked appearance. It is just as

21. Drilling Long Holes. In many cases it is desired to bore holes of small diameter, but of great length, as of a tube; such, for example, as core barrels for rock drilling,

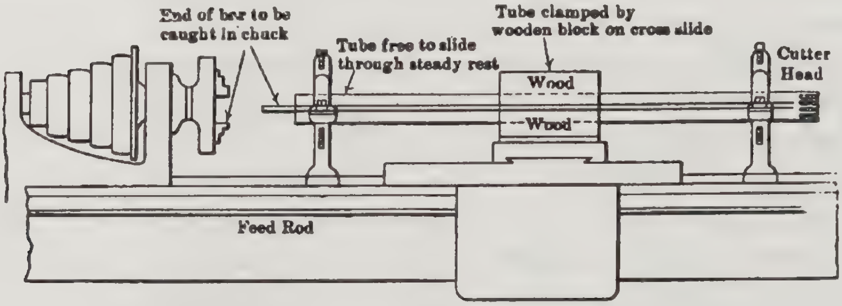


Fig. 52.—Boring Long Holes of Small Diameter.

where the tube is from 10′ to 14′ long and as small in some cases as 2″ in diameter.

Fig. 52 will give an idea of the method by which such holes may be bored with very satisfactory results, and in

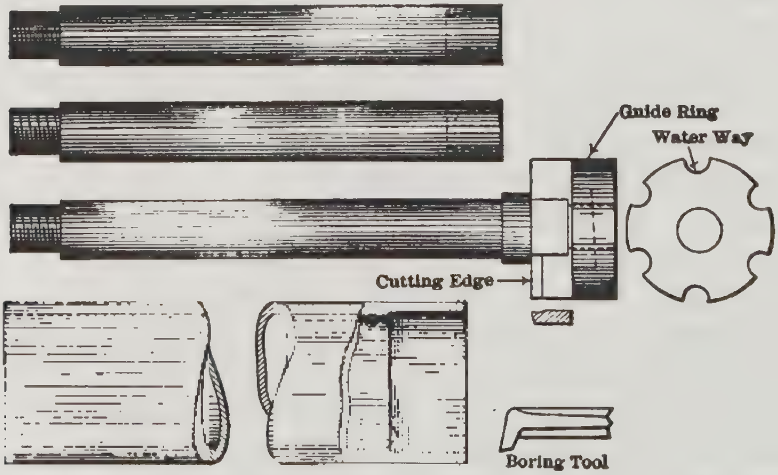


Fig. 53.—Boring Bar.

Fig. 53 the boring bar is shown in detail. The bar is made up of sections, say 3′ long each, so constructed that they can be joined together into one long bar. The work is sup-

ported in the lathe by two steady rests and is clamped to the carriage of the lathe by means of wooden clamps, specially constructed to suit each individual case. The steady rests are only used to guide and support the tube as the carriage advances, carrying the tube with it. The end of the tube is first bored to a depth of about 2″ with the ordinary boring tool, and made the required size. The bar is then inserted until the cutter head reaches the bored end of the tube, which the guide ring on the outer end of the head should fit nicely. The tube is then clamped to the carriage, supported by the steady rests, and the other end of the bar is held by the lathe chuck. Allowance should be made for the tube to travel a distance equal to the entire length of one of the boring-bar sections. When the tube is advanced this far, one of the sections of the bar is unscrewed and laid aside and the chuck engages the end of the next section, and so the work proceeds until completed. It should be observed that the face only of the tool should be used as a cutting edge, while the outside simply acts as a guide.

22. The Counterbore. In Fig. 54 is shown another common type of boring tool more generally known as a counterbore, but it is used to a great extent as a boring tool proper. It is important that there be two cutting edges, to balance or equalize the resistance and insure round holes. Too often we find it used as a fly cutter, as shown at the left in Fig. 54, without the advantage of speed which is essential to the success of a fly cutter. When the cutter takes up its work, the resistance due to the chip tends to push it away, and this strain is carried entirely by the bushing or guide pin of the bar, resulting in the lapping out or uneven wearing of the hole. This means only one thing,—the counterbored part will be neither round nor of the size intended.

When a piece of work is irregular in shape, and in cases where the boring mill is not available, the drill press must be converted into a vertical mill. The work is clamped

to the table of the drill-press and the boring bar is carried by the drill spindle at its upper end, and is guided at its lower end by a bushing in a hole at the center of the table. This is also shown by the left-hand cut in Fig. 54.

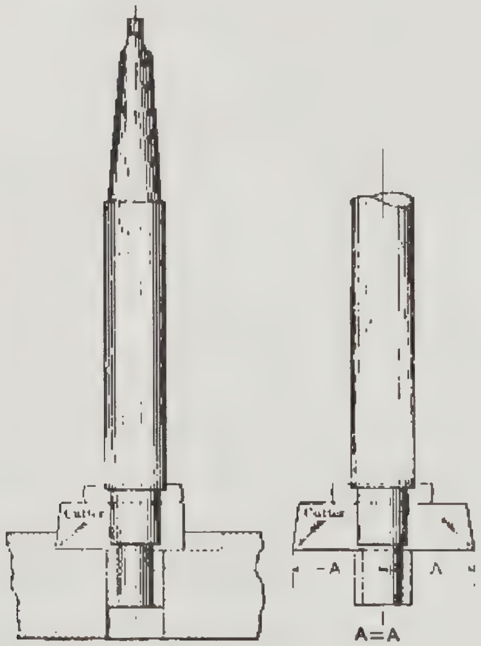


FIG. 54.—Counterbore.

QUESTIONS

1. Describe in detail the essential features of a well-made drill.
2. What should be the angle of the lips of a drill with the longitudinal axis, for cutting iron and steel? For brass?
3. What is a sure indication of the lip clearance on a drill? Give sketches illustrating this clearance, as well as a description.
4. What is the effect of too much clearance?
5. Give sketches showing the result of improper grinding of drills. Explain these.
6. What is the result of using a drill with a thick point?
7. If a drill runs out of center in starting a hole, how may it be drawn into center again?

8. How would you start a drill where very accurate work is required?

9. Give a sketch of a " farmer " drill, and tell on what class of work it is used.

10. Give a table of feeds and speeds of various sizes of drills.

11. Give sketches and description of method of drilling very deep holes of small diameter. How is the boring bar constructed? How is the work fed to the boring tool? For what are the steady rests used? How is the cut started?

CHAPTER VII

PLANERS AND SHAPERS —PRACTICE

Planer Principles

Their proper classification. Fundamental principles. Clamping the work. Strains, their action on work. Feeds and timing of same. Setting up tools. Appliances for planer and shaper for different types of work. Value of parallelism between the cross-rail and platen. Methods of proving parallelism. Method of proving accuracy of vise. Order of handling work. Apron and its function. Shapers.

The mere doing of work is to the workman what dessert is to a good dinner; it is the study of conditions and methods which is really the substantial meal. The valuable man is he who can plan these methods after acquainting himself with the conditions; the cheap man can carry them out. This chapter will deal with conditions the understanding of which is essential to the mechanic, be he machinist or engineer.

23. The Planer. The planer is the simplest of machine tools to manipulate, and one can obtain fairly good results with limited knowledge of the tool itself. It is designed to take in a wide range of work with respect to size and weight.

The first important point to observe is that conditions change every time the cross rail is raised on the housings to accommodate the machine to varying heights of work. Observe that the means of raising the cross-rail is by screws at either end, these screws receiving their rotary motion by means of bevel gears engaged from a common shaft, Fig. 57. This method does not give assurance that both

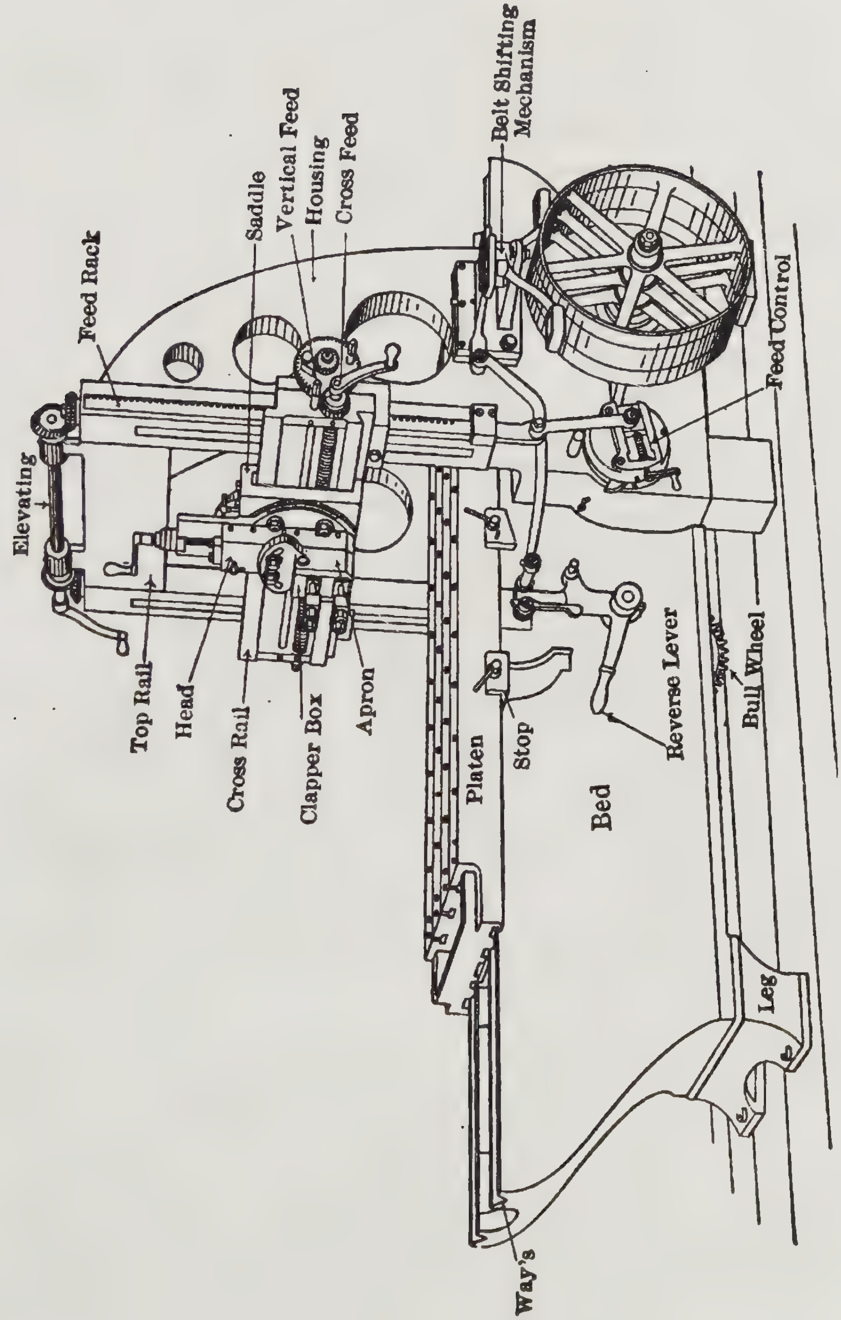


FIG. 55.—C. A. Gray Planer.

FIG. 55.

Legs (C. I.)	Bed (C. I.)	Ways (C. I.)	Platen (C. I.)	Work Rack (C. I.)			
		Bull wheel (C. I.) and (Pinion (Steel) Feed mechanism (Steel and C. I.)	Saddle (C. I.)	Head (C. I.)	Apron (C. I.)	Tool post (Steel)	Tool (T. Steel)
			Feed screw cross (Cru. steel) Feed rod vertical (Cru. steel)				
		Housings (C. I.)	Cross-rail (C. I.) Top rail (C. I.)	Elevating mechanism (Cru. steel)			

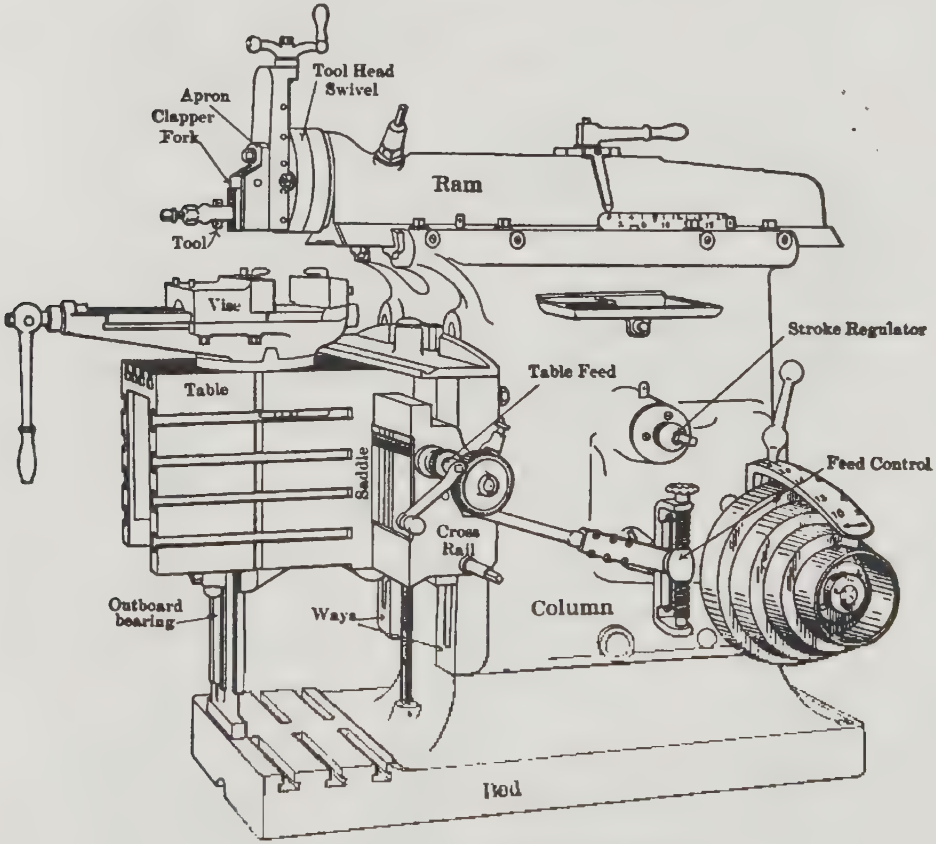


FIG. 56.—Gould and Eberhardt Shaper.

Bed (C. I.)	Box column (C. I.)	Transmission cone and shaft (C. I.) (Cru. steel)					
		Ways (C. I.)	Cross-rail (C. I.)	Saddle (C. I.)	Tables (C. I.)	Vise (C. I. and steel)	Work
				Feed screw (Cru. steel)			
		Ram (C. I.)	Tool head (C. I.)	Apron	Clapper box (C. I.)	Tool post (Cru. iron iron and steel)	
		Elevating screw (Cru. steel)					
		Main spindle (Cru. steel)	Bull wheel (C. I.)	Rocker arm (C. I.)			

ends will rise to the same height. Understand that this is no criticism of the design of the machine, but that the new condition is correct is too often taken for granted and possible errors are ignored.

If the rail does not rise equally at both ends (and in nine cases out of ten it does not), it will not be parallel to the platen, a condition upon which the accuracy of our work

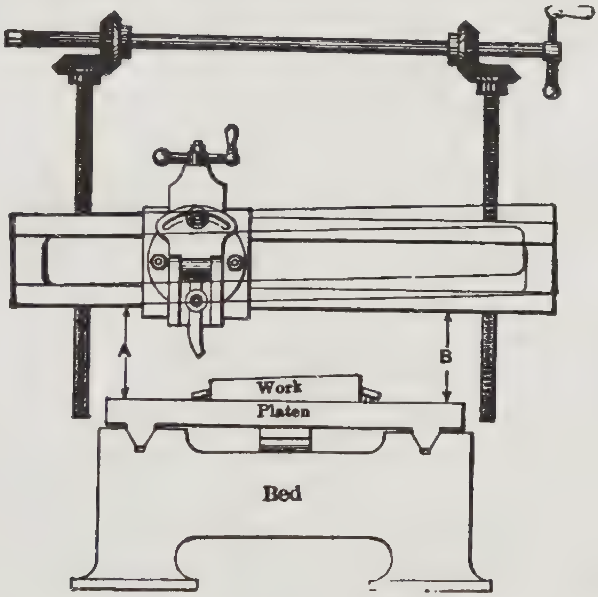


FIG. 57.—Raising and Lowering Gear of a Planer, showing the action of uneven setting at the sides, dotted lines showing uneven setting and the wedge showing the resulting work. Distances *A* and *B* should be equal.

depends. The work will be planed wedge-shaped, as in Fig. 57. Therefore it is evident that this condition must be important, and that errors must be corrected.

24. Testing for Parallelism. The first duty of the operator, then, is to prove the correctness of the relation between the cross-rail,—on which the tool head travels—and the platen. This is done readily by placing a rod or a tool in the tool post and, by means of inside calipers or a stand-

ard plug gauge, getting contact on the extreme ends of the rail. If any difference exists, loosen the nuts which hold the cross-rail, on one side only, when, by means of the handle, the cross-rail can be adjusted the slight amount necessary.

A more accurate way to obtain parallelism is shown in Fig. 58. Use a round rod with convex end, leaving only a point contact; bring this rod down by means of the screw which operates the tool slide, to within a few thousandths of an inch of the platen and, by means of a piece of hard paper

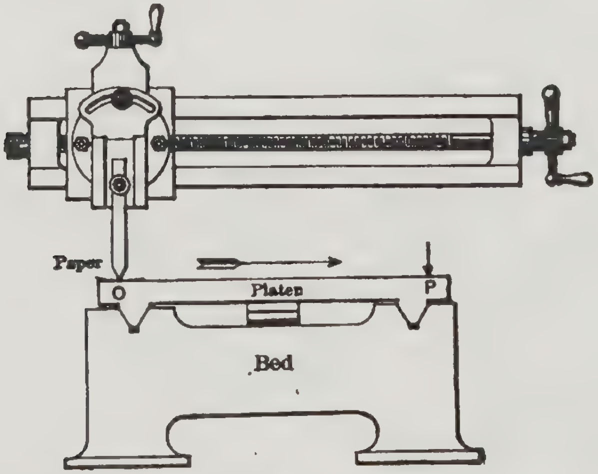


FIG. 58.—Method of Testing for Even Setting. Contacts at O and P should be the same.

such as a white envelope, get a contact, using the paper to feel the contact, and then proceed as before. This, of course, refers to work that is clamped directly to the platen, but in many cases the work is held in a chuck clamped to the platen. In such case other conditions enter which are not taken care of by the same means, although this should always be the first condition looked to.

25. Determining the Proper Position of the Jaw. In chuck work on a planer, or in vise work on a shaper, the movable jaw of the chuck is constantly subjected to wear, and is used only as a clamping jaw; so the second important

point to determine is whether the stationary or dead jaw of the chuck is at right angles to the plane of the tool travel. This is done as shown in Fig. 59, by delicately clamping a true square in the chuck and getting contacts on the extreme

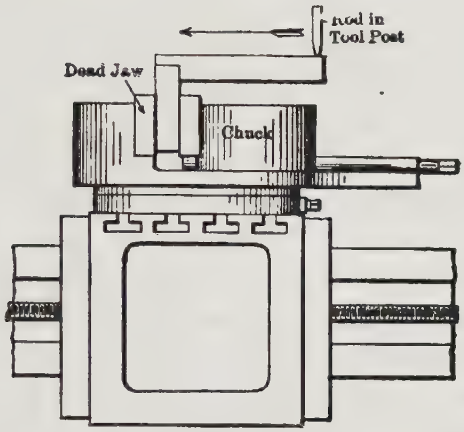


FIG. 59.—Testing Accuracy of Travel of Shaper Tool.

ends of the square blade as we did on the planer platen. If an error exists, the jaw should be taken off and ground, or packed with thin sheet metal, until the error is corrected.

26. Planing a Parallel Strip. With the best of conditions, however, unless the student executes his work

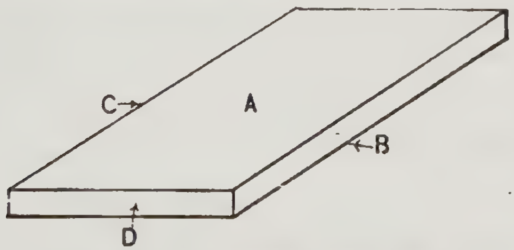


FIG. 60.—A Parallel Planer Strip.

in logical sequence, he will have trouble in planing or shaping a piece square and parallel. To better illustrate what difficulties are to be met, we will consider the operations in planing the simplest piece of work,—a bar of cast

iron designed for blocking purposes and commonly called a parallel strip, Fig. 60.

In beginning actual work on the planer, first study what you are going to do. Plan the method which will bring the result you desire. Different metals require different methods; for instance, cast iron will need different chucking or clamping on the platen of the planer than wrought steel. Why? Because the making of a casting is such that it has certain conflicting strains and tensions upon it, due to the outer surface becoming chilled from contact with wet sand and air while the inner part is still warm and expanded. This places a strain upon the scale or skin of castings. The removal of this scale from any side allows the metal to adjust itself to these internal strains, and the new surface will not be true; hence, to get accurate results in planing castings, rough out the work all over, and afterward finish. This same law will hold good in machining castings on a planer, shaper or lathe.

It must be remembered, too, that a certain amount of draft is given to all patterns, to enable the molder to draw them from the sand hence the castings will not have parallel sides to start with.

In work of this character, therefore, one of the largest flat surfaces, *A*, Fig. 60, should be machined first and used as a working face. The face *A* is then clamped against the true or dead jaw of the vise and the edge *B* machined, after which the opposite edge *C* is finished, keeping the working face, *A*, always against the dead jaw. Lastly, *D* is planed.

This order will insure accurate planing. The reasons for this method are as follows: We know that the sides of the casting are not parallel, to start with; we know that the movable jaw is constantly subjected to wear so that,

Note. The first three pages of Chapter IX, Cutting Tools, should be carefully studied in connection with this consideration of the planer.

in clamping work, as soon as the pressure necessary to hold the work is brought to bear upon it, this jaw raises according to the amount of wear, and tends to lift the work with it. The jaw will, invariably, conform to the irregular sides of the casting, so that, as one flat side is machined and we attempt to machine the opposite side, this difficulty always confronts us. A good method for overcoming this tendency to raise the work is to insert a round rod, as shown in Fig. 61; any lifting of the movable jaw creates only a rolling motion on the rod, and does not affect the work.

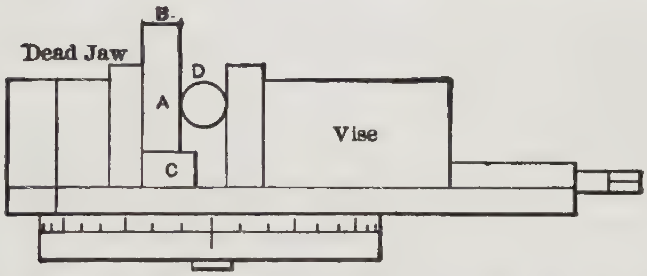


FIG. 61.—Device for Getting True Work in a Planer Chuck.

27. Wear on the Tool. The tool-holder proper, indicated by *B*, Fig. 62, being pivoted on the rod *F*, provides for the lifting of the tool, primarily to avoid wear on the tool during the return stroke of the machine, in horizontal planing. This wear will be obviated in some degree if the machinist gives proper attention to the timing of the feed of the tool. Let us see if this is not an important point: The resistance of the cut or chip to the tool is granted; this causes two deflections of the tool, the horizontal, which tends to push the tool back from the chip, and the lateral, which tends to push it away from the work, sidewise. This lateral deflection or spring is at right angles to the plane of the cutting edge, as illustrated in Fig. 63. This means that the tool does not cut its full feed, but springs away from the work, and this makes it necessary to design the tool box to lift on the return stroke, and ride free. As it is not

deflected by resistance upon the return it drags slightly, producing wear upon the tool. If, now, the feed takes place at the end of the stroke, the tool has to drag back over the metal that has not been cut, and the wear on the tool is proportionately increased. The feed should take place, therefore, between the point of reverse and the begin-

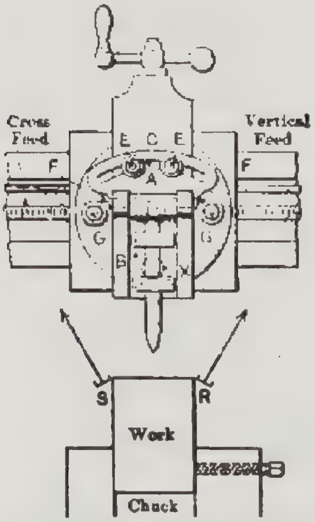


FIG. 62.—Setting for Planing Vertical Sides: slack up bolts *EE* and set the head as indicated by the arrows. For dovetailing, loosen bolts *GG* and turn the head the required number of degrees.

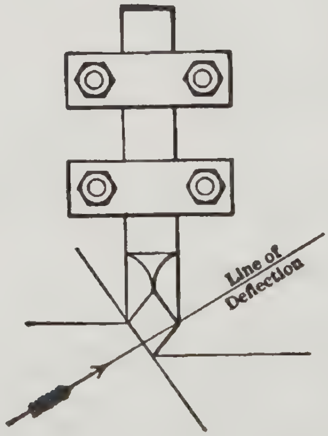


FIG. 63.—Direction of Deflection.

ning of the cut, enough distance being allowed in setting the back stop to insure the full feed, and if a little air is cut, from which no chips can be seen, the loss will be more than made up in the saving of the operator's time in grinding and resetting the tool.

28. Function of the Apron. The reasons now being clear why the tool box is made to lift, a word about the apron, of which the tool box is a part. Its function is too

often ignored, sometimes intentionally but more often from ignorance. That it has a distinct use is apparent from its careful construction. It is so arranged as to swing on a pivot which is located at about the center, *X*, of the box, *B*, Fig. 62; from this center the arc, *C*, is described. In vertical planing, the apron is moved right or left depending upon which side the machinist is working. This moving from the vertical position changes the center line of the tool so that, in rising, the tool swings away from the work and is relieved from drag on the return stroke. Fig. 62 indicates by arrows the direction of apron throw; planing to the right, *S*, and to the left *R*.

29. Clamping Work. In working directly on the platen, the first important step, after seeing that conditions are right, is the clamping of the work upon the machine. If a piece of work were laid on the platen with no stops or clamps to hold it, and the machine started, the work would be shoved along bodily, as soon as the tool came in contact with it; hence the first step should be to see that proper stops are placed to resist the cutting force. As there is really no tendency on the part of the tool to raise the work, only sufficient clamping is necessary to keep it solid. The work should be well wedged if it does not rest level on the platen, especially under the clamps, so there will be no spring of the work due to clamping, but in every case the clamps should be relieved of most of their strain before taking the finishing cut.

There are many devices for clamping work, but these again are only secondary; the prime feature, as indicated, is to have the work clamped without spring.

In clamping, another thing too lightly considered is the fulcrum of the clamp. In common practice this is mors tightly clamped than the work itself. Fig. 64 will illustrate clearly this point.

For very thin work a good method of clamping may be found by gashing in each end of the work with a milling saw,

as in Fig. 65. Another convenient appliance is illustrated in Fig. 66. It acts as stop and clamp, and is cheaply constructed.

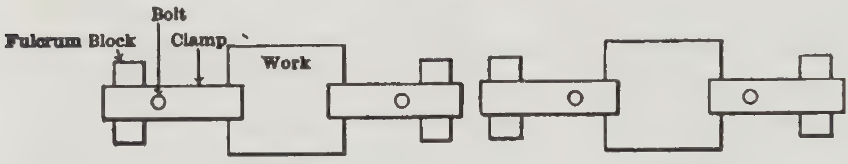


FIG. 64.—Clamping Work.

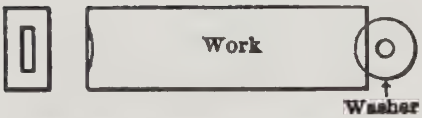


FIG. 65.—Clamping Thin Work.

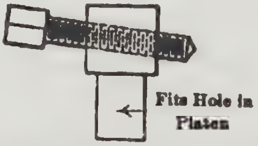


FIG. 66.—Convenient Clamping Device.

30. Use of the Centers. The pair of centers which belong to every planer are often not used to the full extent of their usefulness. They are valuable for more than circular work. They will be found very convenient for all kinds of rectangular work that ordinarily is done in the chuck, as well as more economical, for when once set up the parallelism is assured. This is not the case with the chuck, where reliance must be placed on the skill of the operator each time the work is turned, because in most cases it is impossible to bed the work on the bottom of the chuck. Therefore, parallel strips are used, thus multiplying the chance of error by four, namely the bottom of the chuck, the bottom of the parallel, and the top and the bottom of the work itself. If any doubt exists in the mind of the mechanic as to the accurate alignment of the centers, all that is necessary for him to do is to turn the work end for end and he is assured of parallelism. In Fig. 67, side 1 is planed, after which it is turned end for end

and upside down, and side 2 is planed. The illustration should be sufficiently plain.

31. Planing at an Angle. The whole tool head of the planer or shaper swings on a common center, and the graduations on the circular part, indicating degrees, enable

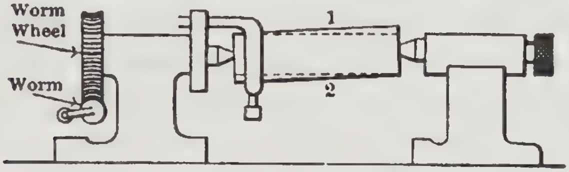


FIG. 67.—Planing with Centers.

the operator to plane at any angle he desires for dovetailing. However, here is another little thing worth noticing: Don't take for granted that, when you have set the head over to the desired degree, it will plane that angle, for very often it does not; the side may be worn, and not straight; and again the lines of graduation are quite wide, so that it is

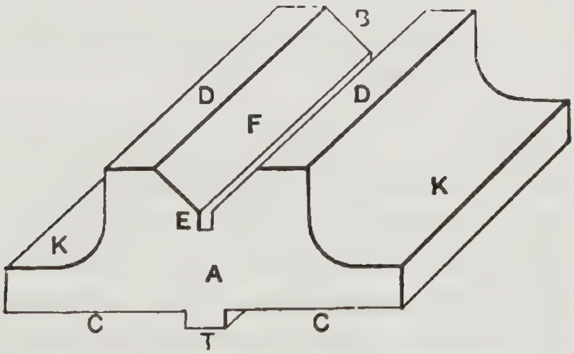


FIG. 68.—V-block for use on Planer Bed.

difficult to get an accurate setting. When it is important that the angles on both sides of the piece should be alike, the proper course is to make allowance for turning the work, side for side, and allow the head to remain in its original setting. To illustrate the planing of oblique surfaces by

swinging the whole tool head, let us take a set of V-blocks and plane them from the rough.

V-blocks are used as master appliances on planers, for holding bars, piston rods, etc., and must of necessity be accurately aligned and planed. Fig. 68 will give a clear idea of their proportions. The full set, either two or four, is clamped to the planer and the side *A* is planed, after which they are reversed, and the opposite side, *B*, is planed.

The sides *A* and *B* are planed on all the blocks. They are then all gripped together in a chuck and the sides *CC*

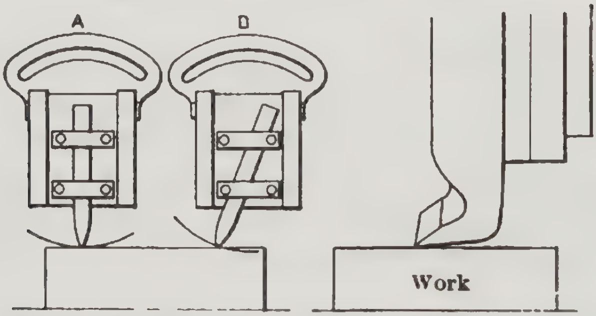


Fig. 69.—Method of Setting Tool with Proper Clearance and at Right Angles to the Work.

are planed, leaving the tongue *T* to fit the slot in the platen accurately. The blocks are then placed on the platen in their proper slot, clamped on the sides *KK*, and the edges *DD* are planed. A square-nose tool is used to plane the slot *E* for the tool to run out. Lastly, for the sides *FF*, the tool head is swung round to 45°, and one side is planed; then the clamps are loosened and the work turned to plane the opposite side of the V. This not only insures the same angle, but will bring the V in the center of the block, central with the tongue, which is an advantage in setting the block for many pieces of work.

32. Tool Setting. Fig. 69 will give some idea of tool setting and clearance. The apron should be run well down and

the tool gripped short to avoid spring in the shank of the tool. As indicated at the left, the tool should be set at right angles to the face of the work. When so set, any side motion will let the tool draw away from the work, as at *A*. If set as at *B*, the side-wedging action of the cutting point drags the tool into the work and makes it difficult to get a true surface.

33. Planing Arcs. A device for planing arcs of different radii can be cheaply and quickly built and is a very convenient fixture, and one that will be found useful in very many

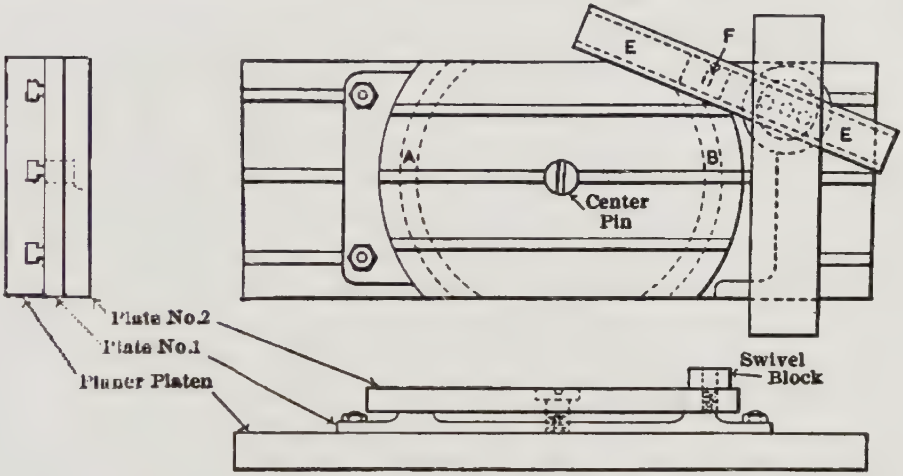


FIG. 70.—Device for Planing Arcs.

cases. The diagram shown in Fig. 70 will illustrate the device. Plate No. 2 pivots on the center pin of No. 1, *A* and *B* being machined surfaces for flat guides. The arm *E* is clamped to the bottom of the cross-rail of the planer, and the slot in *E* fits over a bronze box *F*; as the platen travels, plate No. 2 is given a rotating motion. The radius of the arc is changed by changing the angle of arm *E*.

34. Measuring the Height of the Tool. Another point to be considered is the frequent lax methods of calibration on a planer, especially on work clamped to the platen. It depends entirely upon the skill of the mechanic how accurately he can read the lines of a 6″ or a 12″ scale in meas-

uring the height of the work. Small measuring pieces can be filed and micrometrically calibrated and these used to bring the tool down to the required height, and these can be kept as standard height gauges for all time. See Fig. 71.

35. Open-side Planers. Besides the ordinary form of planer so far referred to, there is the "open-side" planer. In this machine there is a housing on only one side, thus accommodating work wider than could be done on the more common machine. The single housing and the cross-rail are, of necessity, very heavy and strong.

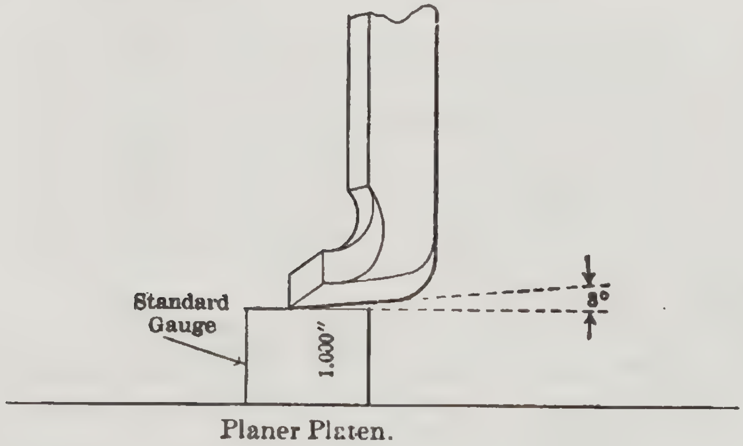


Fig. 71.

36. Shapers. In the planer the work moves against the tool while in the shaper the reverse is true; the tool moves against the work. The planer is suitable for large work demanding heavy cuts with the attendant slow speed; the shaper is adapted to small work requiring lighter cuts and allowing faster speed. Except as to size the same tools are usable on both machines. The student will not find the shaper a difficult machine to understand, especially if he has been introduced, first, to the planer.

There are two general types; in a **geared shaper** the ram is driven by a gear which engages a rack on the ram,

while in the **crank shaper** motion is transmitted to the ram by a " link."

In a **traverse shaper** the ram has an intermittent side motion, in addition to the usual reciprocating movements. The feed is obtained in this manner instead of by the moving of the work, as in the ordinary shaper. Traverse shapers sometimes are made with two rams and usually with two tables; the latter can be adjusted to any desired position.

QUESTIONS

1. Make a sketch of a tool without either side or back rake and explain its action.

2. Is such a tool correctly ground?

3. What class of tools do you study first?

4. Should a planer tool have much clearance? State the smallest amount permissible.

5. Should there be a great amount of top rake on a planer tool?

6. Are you permitted to give considerable side rake?

7. State a second reason why a planer tool is apt to bite into the work, and explain its action in so doing.

8. What may cause a " chattered" surface, on planed work, besides the springing of the tool?

9. Which is the better for producing smooth work on a surface, the rack and gear, or the worm-drive planer?

10. Give a sketch showing how a planer tool may be designed to avoid " biting " into work.

11. Give a sketch showing the ideal form of finishing tool.

12. What is the distinctive difference between a planer and a shaper?

13. Name and describe several different kinds of shapers.

14. How is the spring of the work away from the tool taken care of in the shaper design?

15. What is the function of the apron?

16. How is angular work done on a shaper?

17. Describe the reversing mechanism on planer and shaper.

18. How is quick return obtained? Name several ways and the value of each.

CHAPTER VIII

LATHE PRACTICE

LATHES

Different types and their classification. Main spindle centers and their true value. Value of centering work true. Value of facing work first. Thread cutting. Different forms of threads. Rule for thread cutting. Method of figuring rules. Taper turning. Rule for taper turning. Setting of tools. Grinding of Tools. Speeds and feeds.

37. Principles of Construction and Proper Method of Handling. The first essential in doing a master's work is to know intimately the tool upon which you are going to do the work; know its relation to all others, their relations to each other, and their proper functions so that an intelligent result is obtained.

In order to acquire this knowledge of the engine lathe Fig. 72, page 65, will prove valuable to the beginner. It shows the building-up, step, by step, and the relation of the parts to each other, as well as the names commonly applied to each part. It is also well for every mechanic to be thoroughly familiar with the materials of construction, for through this knowledge he trains his judgment to be sound and also gets a sense of proportion and the eternal fitness of things mechanical.

38. Types of Lathes. The **hand lathe,** having no carriage or power feeds, where the hand tool is held on a rest, and with no thread-cutting facilities other than a hand chaser.

Engine Lathe. A power machine, with power feeds, and several cutting attachments, tool carriage and simple and compound rests. They are enumerated as follows:

Single-geared lathes when the power is transmitted through a single train of gearing.

Double-geared lathes when the power is transmitted through a double train of gears, such lathes being for heavier work.

Triple-geared lathes when the power is transmitted through three trains of gears. These lathes are for still heavier work.

Quadruple—or double-compound geared lathes.

39. Truing the Centers. Assuming that there is no end thrust or lost motion in the bearings of the lathe spindle, the most important thing to observe before beginning a piece of work is that the centers fit in their respective spindles. They should be taken out and cleaned, not with a piece of cotton waste, which leaves lint upon the center, but with a small brush, such as jewelers use, and which should be a part of every good mechanic's kit. A reamer of the same standard taper as the center should be turned around in the spindle by hand, to pick up any particles of dirt or foreign matter which may have lodged there.

Being satisfied on that point, the next step of importance is to prove the live center by running the back of a tool up to it and holding a piece of white paper underneath. Note the slightest variation of the face of the center while running, for it is essential that it should run perfectly true, if accurate work is expected. The live center is usually soft, for there is no frictional wear on it, its function being that of a centralizing support only; being soft, it has the advantage that the operator can true it by turning, without unnecessary delay. Both centers are sometimes hardened now that grinding machines are in so general use; they provide ready means of keeping hardened centers true.

When necessary to true a center, make it a rule never

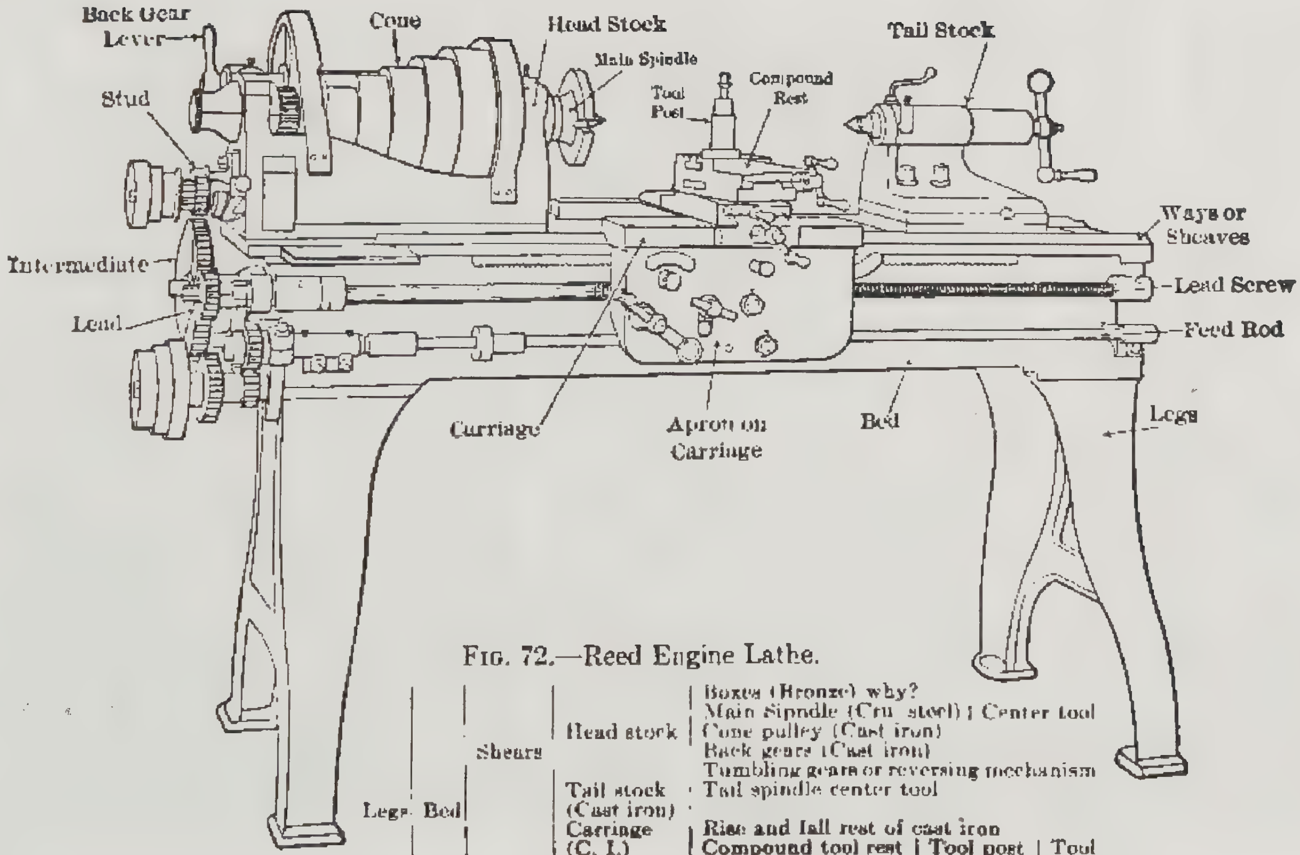


Fig. 72.—Reed Engine Lathe.

- Legs.
- Bed
  - Shears
    - Head stock
      - Boxes (Bronze) why?
      - Main Sipndle (Cru. steel) | Center tool
      - Cone pulley (Cast iron)
      - Back gears (Cast iron)
      - Tumbling gears or reversing mechanism
    - Tail stock (Cast iron)
      - Tail spindle center tool
    - Carriage (C. I.)
      - Rise and fall rest of cast iron
      - Compound tool rest | Tool post | Tool
      - Apron | Feed Mechanism
  - **Lead screw (Crucible steel)**
  - **Feed rod**
  - **Thread gearing mechanism**

to use a file for finishing, but tool it true, and this, by the way, is a good rule to follow on all work. It is an utter impossibility to file work round in a lathe, if for no other reason than that you cannot maintain equal cutting pressure throughout the entire length of the file stroke. For turning the center there are several tools which might be used, but perhaps none is more efficient than a side tool used, as in Fig. 73, by running the lathe backward and having the side tool set level. The angle of the center is 60°; use the center gauge in testing it. The entire face of the center should not be cut at once; it should be cut

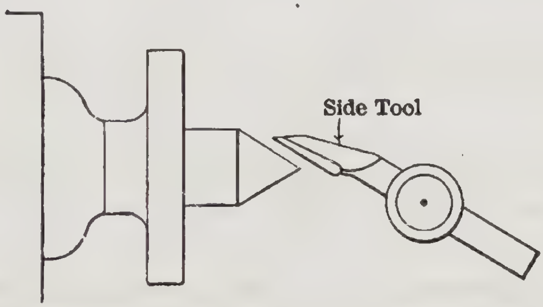


Fig. 73.—Use of a Side Tool for Truing the Live Center.

down part at a time, beginning at the point, taking care to make it straight.

40. Alignment of Centers. The third step of importance is the alignment of centers to insure parallel turning. Ordinarily, the operator will push the tailstock up until the two centers meet, and line it by the eye, but this is only an approximation and its value depends entirely upon how good an eye the operator has. A sure way to test the center for alignment is shown in Fig. 74.

The work itself, if it is to be a plain cylinder or piston rod or piece of shafting, can be used for the purpose, or any old mandrel or piece of scrap rod, always to be found around a shop, will answer. The piece is placed on the centers, the tool brought up to within a short distance of the carrier,

and a light cut taken just wide enough to allow a micrometer measurement to be made; the work is then taken from the centers and the carriage moved down to the dead center end of the work without changing the cross-travel of the tool. The work is again placed on the centers and a

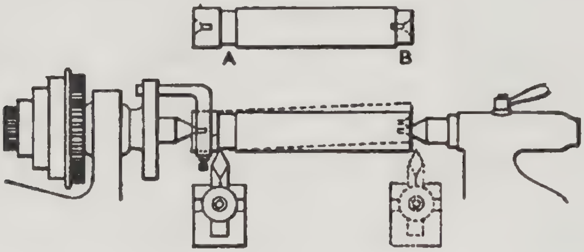


FIG. 74.—Testing for Alignment of Centers. Dotted lines show piece as held off center while moving the tool over for the second cut.

cut taken on the extreme end of the rod; if the micrometer measurements of the two cuts are alike the centers are properly aligned. Any adjustment that is necessary is easily made by means of the screws on the side of the poppet head. After adjustment the same testing process should be repeated.

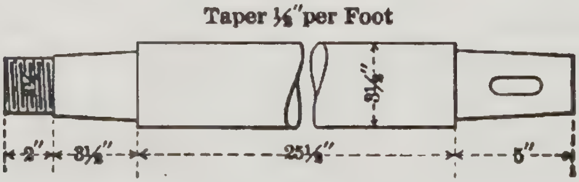


FIG. 75.

41. Centering. The various steps in lathe practice may best be explained by assuming an actual piece of work as, for example, the piston rod of an engine, and going through the various operations from roughing to finishing as in the following paragraphs. Assume the rod to be of forged steel, to be finished to the size indicated in Fig. 75.

First, it is important that the work be carefully centered, no matter how much stock is left for finish, for the nearer the cutting resistance comes to being uniform the nearer round will the piece be turned. The drilled hole should be so deep that the point of the center will not touch the bottom of it; see Fig. 76. This prevents wear of the point, and insures the bearing of the work upon the face of the center. The centers in the bar should be made large enough to carry the weight, and also to withstand the crushing effect that takes place during the turning; in a bar of this size the outside diameter of the center when finished should

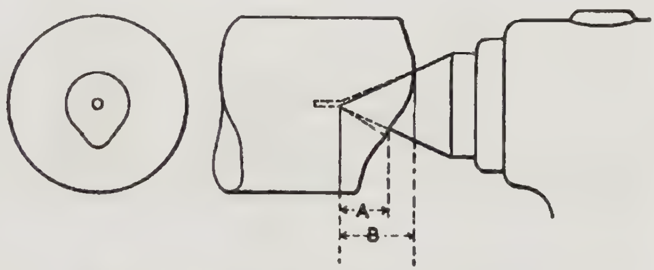


Fig. 76.—Showing the Result of Turning before Facing the Ends. *A* is the length of bearing on one side, *B* on the other. The wear at *A* will be greater on account of the smaller surface to resist crushing.

be about ½″—about one-seventh the diameter. A driver, or dog, is now placed upon one end of the bar and the bar is placed in the lathe. There are various styles of dogs useful under various conditions. In placing a dog on finished work a piece of sheet brass or copper must be used under the end of the set screw or, preferably, a piece long enough to nearly encircle the work, thus taking all points of contact with the dog.

42. Facing the Ends. Both ends of the bar should now be faced; this is an important step before turning, as the following reason should be sufficient to prove: When the turning tool starts to cut, the resistance due to the chip creates a crushing force on the dead center; in other words,

the center resists the tendency of the tool to push the work away, hence an unequal bearing on the center results, if there is a rough end on the bar, and, as the smallest surface will be affected the most, the center will wear out of round. Fig. 76 will illustrate the point.

43. Turning. A roughing cut is next taken, and here the tool conditions must be studied. The cutting angle of the tool should be about 55°. The tool should be set with the post well up to the work to obtain rigidity, and

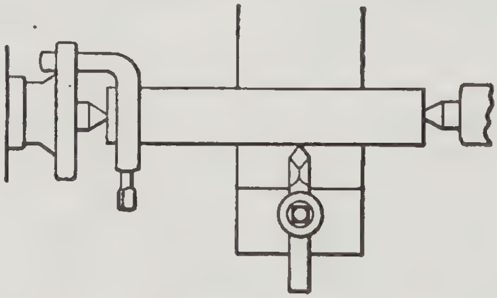


Fig. 77.—Proper Position of Tool Post and Tool.

at right angles to the axis of the work, thus eliminating the possibility of the tool being drawn in during the cutting process.

Note. Those portions of Chapter IX on Cutting Tools, relating to lathe tools, should be carefully studied in connection with the preceding paragraphs.

44. Cutting the Thread. After roughing the work, the next step is the cutting of the thread for the nut. The advantage of this order is that the thread cutting requires more skill than plain turning, so, if any accident happens by which the thread end is spoiled, the time required for turning and finishing the whole rod and fitting the tapers is thereby saved.

The student should be thoroughly familiar with the

more common screw threads. Fig. 78 shows them. The first is the **simple V-thread** cut to a sharp point at the top and also at the bottom or root, the angle being 60°. For cutting this thread it is obvious that the tool must be ground to a sharp point having the same, 60°, angle. The center gauge is used for testing the angle of the tool and also in setting it in the tool post of the lathe, see Fig. 94. The top of the V-thread is easily bruised and the diameter of the work, at the bottom of the thread, is less in the case of this thread; hence, the thread next mentioned is, in these re-

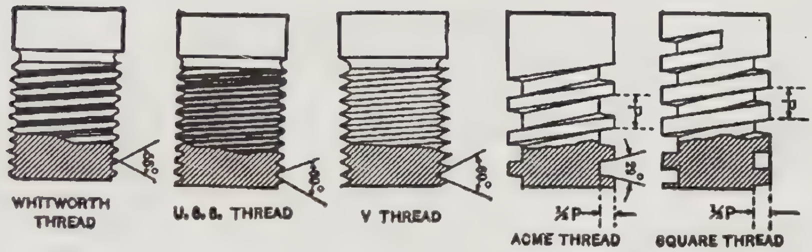


Fig. 78.—Screw Threads.

spects, superior. It is also difficult to retain the sharp point of the tool in cutting the V-thread.

The second is the **United States Standard** (U. S. S.) **thread.** This has the same angle as the V-thread, but the top and bottom of the thread are made flat an amount equal to $\frac{1}{8}$ of the depth or pitch; for example, for 8 threads per inch we have $\frac{1}{8}$ of $\frac{1}{8}'' = \frac{1}{64}''$ flat. The tool is ground to conform to this shape.

The third is the **square thread,** which is as wide at the top as at the root, the sides being parallel; the depth is ordinarily made equal to the width.

The fourth is the **acme thread,** intermediate between the square and the U. S. S. It is much used for the lead screws of lathes. The angle is 29°.

The fifth is the **Whitworth thread** (English) having an angle of 55°. Instead of being flat at the top and bottom it is rounded an amount equal to $\frac{1}{6}$ of the depth.

For general use the U. S. S. is the best thread. There is recognized, as standard, a certain number of threads per inch for each diameter.

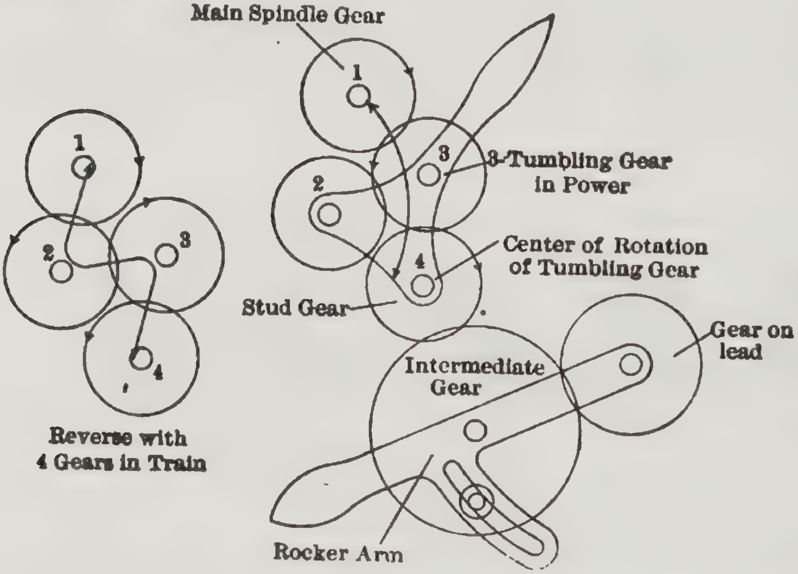


FIG. 79.—Arrangement of Gears for Thread Cutting.

45. Calculating the Gears for Thread Cutting. Modern lathes have tables of change gears for the different threads screwed to some part of the machine, but the thinking person will admit the wisdom of knowing how to figure the different gears without depending upon the table. A simple method is here given, which will enable even a novice to calculate the changes: Thread cutting is regulated by the different ratios of speed between the main spindle, or cone, and the lead screw; hence, we find the number of threads per inch on the lead screw and use this as the numerator of the fraction or ratio, and the number of threads to be cut as the denominator; for example, the number of threads

per inch on the lead screw may be 4, and the thread desired on the piston rod, 8, then

$$\frac{\text{threads on lead screw}}{\text{threads desired}}=\frac{4}{8}.$$

If we had a gear with four teeth and one with eight, we could cut the thread with them, but as such small gears are impossible, we multiply by some number, even or odd, according to the pitch of the gears on the lathe. In the majority of the lathes, the gears run in even numbers, such as 24, 28, 36, 40, 44, 48, 52, and so on, hence 4 or 8 would be a good number to multiply by and we have

$$\frac{4}{8}\times 8=\frac{\text{32 stud gear teeth}}{\text{64 lead screw gear teeth}}.$$

Again, on a lathe where the gears run, as in some cases, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98, etc., 7 or 14 would be the number by which to multiply. Then

$$\frac{4}{8}\times 7=\frac{28\text{ (stud)}}{56\text{ (lead)}}.$$

The formula explained above holds good on all lathes in which the main spindle and stud are run at the same ratio; where the ratio changes and the stud runs half as fast as the spindle, multiply the numerator by two.

46. Lubricants and Tools. A fibrous material such as soft steel or wrought iron should be cut with a lubricant, which serves a double purpose—to keep the cutting edge of the tool cool, and to reduce friction between the chip and the tool. Soda mixed with water will prove effective, soda being introduced chiefly to prevent rust on the machine parts.

The cutting edges of all tools should be kept as keen as possible at all times, by oil stoning. The thread tool should be set absolutely level and on a plane with the center of work.

47. Cutting the Taper. The next step after the thread is the cutting of the taper. Not every lathe has the taper attachment, hence the poppet head or tailstock must be set over. The taper given in our suggested exercise is $\frac{1}{2}''$ per foot, and the following sample formula will give the throw-over of the poppet head: Find the taper in 1″, multiply by the length of the piece over all, and divide by 2.

$$\frac{\frac{1}{24}\times 36}{2}=\frac{36}{24}\times\frac{1}{2}=\frac{36}{48} \text{ or } \frac{3}{4} \text{ inch,}$$

Note. The author uses an inch as the unit of measurement instead of a foot, because a great deal of the work is under a foot in length. Divide by two because the diameter is double the radius.

Remember, no matter how short the taper desired, the length of the whole piece of work is what is affected by moving the dead center out of alignment, as the whole piece swings on the live center. If this rule is carefully applied and the poppet head carefully moved, accurate results will be secured.

In shops where such rods are made in great numbers and kept in stock, a **taper sleeve** is used as a gauge for proving the taper as the operator proceeds with the work. In railroad repair shops usually the screw head and piston head are used for fittings; if properly fitted, $\frac{1}{8}''$ is ample allowance for " drawing home."

48. Finishing. There is left now only the plain turning of the rod, and in the modern shop of to-day the rod is turned only to within an approximate size, say $\frac{1}{32}''$, and is then ground to standard size on a grinding machine. If, however, there is no such machine in the shop, it must be turned to size, in which case a **ring-gauge** of standard size is used to follow up the cut. The tool should have just enough of a flat point to cover the feed; for instance, if the feed were 60 revolutions of the work to 1″ feed, we should say

QUESTIONS ON LATHES

1. What precautions must always be taken, in connection with the lathe centers?

2. How is the live center turned up?

3. Which center is hard and which is soft?

4. Is it good practice to use a file on lathe work?

5. What tool do you use for truing a center?

6. What is the third step of importance when starting a lathe? How may this step be performed approximately? How accurately?

7. Is it important that all work be centered true, regardless of the amount of stock to be removed? Why?

8. What proportion of the whole diameter of the piece do you commonly make the center hole?

9. Should the ends of a piece be faced before starting to turn it? Why?

10. What should be the angle between the side faces of the diamond point?

11. How should it be set in the tool post?

12. If you have a lathe furnished with a 6 per in. lead screw and you wish to cut 15 threads per in., what gears, of the following, would you use—32, 36, 40, 66, 72, 80, 86, 90, 98?

13. At about what speed should tool steel be machined?

14. What is meant by the term "feed"?

15. Give the proper feed for cast iron.

16. Give the proper feed for tool steel.

17. A piece of tool steel $\frac{3}{4}''$ in diameter is to be turned in a lathe; how many revolutions per minute should the lathe make to give a cutting speed of $40'$ per minute?

18. Should the number of revolutions be reckoned while the lathe is running free or while the tool is cutting?

19. A piece of tool steel $\frac{7}{8}''$ in diameter is turned in a lathe at 168 revolutions per minute. Find the cutting speed.

20. A lathe has a feed rod turning at the same rate as the lead screw, while the carriage travels one-quarter as fast as it would when screw cutting. If geared for 12 threads per inch, and the feed rod is used, what will be the feed?

21. In the preceding question, if the lead screw has 6 threads

per inch, and the gears, 24, 36, 48, 72, were at hand, how would you gear the lathe? Give stud and screw.

22. Is it possible to get a perfectly accurate feed on a lathe with belted feed rod? Why?

23. If a lathe has a three-stepped cone on the feed rod, how many feeds are possible? How could you obtain more?

24. How would you cut a left-hand thread on a lathe with no tumbler gears?

25. What is meant by compounding lathe gears? Does this change the direction of thread, i.e., right or left hand?

26. A lathe has gears 32 and 64 for cutting 8 threads per inch. How could these be compounded to cut 16 threads per inch? Draw a sketch of the train of gears you would use.

CHAPTER IX

CUTTING TOOLS

Turning Tools

Turning tools. Different forms. Leverage. Difference between planer and lathe. Tool angles of clearance and why. Correct rakes and angles. Setting of tools. Cutting force for different metals. Cutting speeds and feeds.

50. Cutting-edge Principles. Proper Angles, etc. Planer tools will first come under notice as being the simplest and requiring the least skill in setting. You have doubtless observed that if the chip be unwound from the spiral shape it assumes in leaving the tool, and projected in a straight line, it is shorter than the surface from which it came. This is due mainly to the compression of the metal in the direction of the cut, and you will thus see the possibilities of saving power and strain upon the machine by giving proper cutting angles to the tools and reducing this compression to a minimum.

In Fig. 80, the cutting tool is at right angles to the work without rake. It exerts its force in a direction nearly parallel to the surface of the work, and, having no rake, it simply does not cut, but shoves or crowds the metal forward, producing a chip made up of little splints. It cannot exert any force to lift or curl the chip. This tool is wholly wrong, nor would it be materially improved if ground like the tool shown in the little sketch at the right, which shows the other extreme; a tool so ground would spring downward into the work.

A tool must first of all be heavy enough at the back or heel to resist the horizontal cutting force, and consequently should have very little clearance.

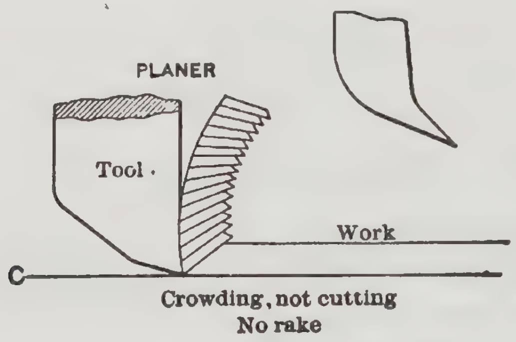


FIG. 80.—Improperly Shaped Tools.

The 7° clearance shown in the lathe tool in Fig. 81 is too much for a planer tool, while the 3° of the lower sketch is as small as can be used safely. Theoretically, if the

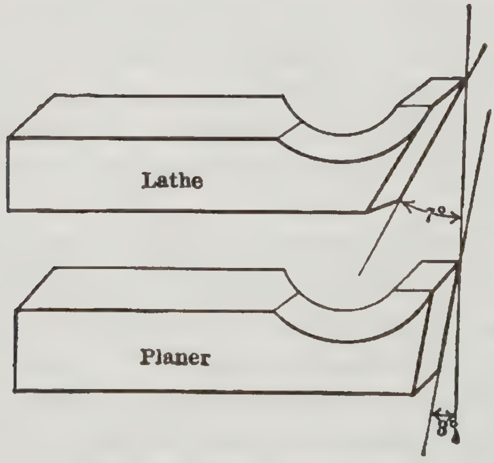


FIG. 81.—Tool Clearances.

point of a planer tool leads, due to its rake, by only a thousandth of an inch or two, it will perform its function. There should be very little back rake on account of its tend-

ency to make the tool gouge the work; but this can be compensated for by giving considerable side rake.

Another reason why the planer tool tends to gouge the work is illustrated in Fig. 82. Point *A* in each sketch is the fulcrum. In the first sketch the tendency is to push the tool down and back into the work in the direction of the arrow. This is not so serious as appears on the face of it, as planer tools are usually so stiff that they will spring but little and any error that might occur in the roughing

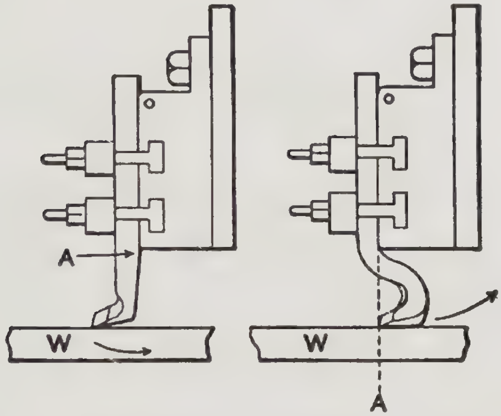


Fig. 82.—Tools which Tend to Gouge the Work.

out would be eliminated in the finishing cut. What many mechanics take as an indication of the spring of the tool is really due to the chatter of the planer, since a rack and pinion planer will frequently chatter after it has become worn, while in a worm-driven planer the lost motion is all taken up at one end before beginning the cut, and the screw action does away with the chatter. To obviate any spring the tool may be designed as in the second sketch, Fig. 82, where the deflection due to the force of the cut is away from the work in the direction of the arrow.

The tool in Fig. 83 approaches the ideal for a finishing tool to be used on a planer or shaper, and gives the best

finished surface. It is made from a piece of ordinary tool steel and forged on the end in the shape indicated. It will be noticed that it has side rake instead of being straight on the bottom; the line that comes in contact with the work is a little rounding.

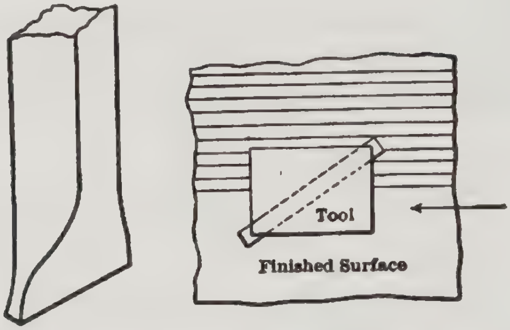


Fig. 83.—An Ideal Finishing Tool.

51. Lathe Tools. The subject of lathe tools will now be considered. Some of the many varieties are shown in Fig. 84, viz., a diamond point, a round-nose tool, a side tool, a centering tool, a thread-cutting tool, and a cutting-off tool. For the lighter, roughing cuts, a round-nose tool, forged on the general lines of the diamond point, is some-

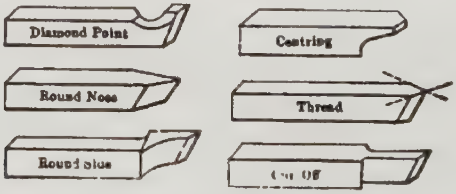


Fig. 84.—Lathe Tools.

times used. It is given rake and may be either right or left hand.

For heavy roughing cuts a modification of this regular round-nose is often used. It is forged with a broad round point, raised enough to give rake, and set over to give clear-

ance. It is stiffer than either the old round-nose or the diamond point, not being tapered, and is more quickly forged than the latter. Diamond points and side tools are forged both right and left-hand. The diamond point will first be considered, as it is more of a universal tool than any of the others.

52. Form of Cutting Edges. Before discussing rake, clearance, or the setting of the tool, attention is called to the general form of the cutting edges, and the importance of maintaining the same throughout the life of the tool.

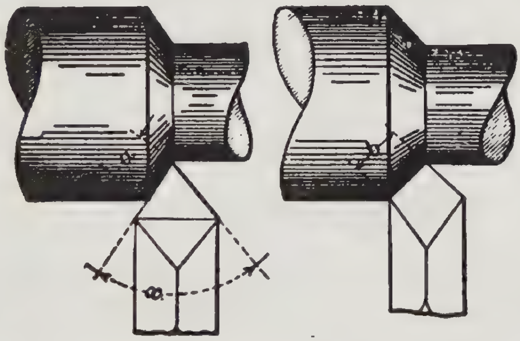


FIG. 85.—Effect of Grinding Tool to Improper Angles.

Fig. 85 will best illustrate this point. The tool is shown at the left, with the depth of the cut, and ground so that the angle shall not be less than 55°. To the right is a tool in which the angle has been changed by grinding on both sides of the point, because the machinist claims that he is in a hurry and must make time on his work. But it will be seen that to do the same amount of work the line of cutting resistance is much greater in *b* than in *a*, showing loss of efficiency in the tool by requiring more power to drive it after it has been ground. This is true even with proper rake and clearance, but when the mechanic also ignores these it becomes much more serious, because more finishing will be required to make the work correct.

53. Spring of the Tool. Fig. 86 illustrates an important point in setting the tool. The farther the cutting edge is from the base, or support, the greater will be the spring.

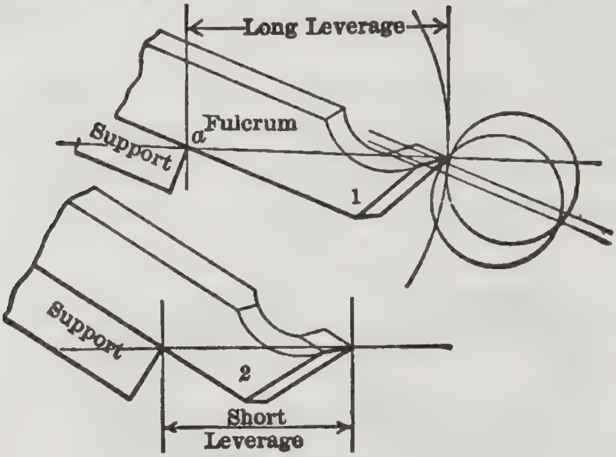


Fig. 86.—Effect of Leverage.

Where this spring is possible, the point is drawn down, as indicated by the arc. This indicates the value of short leverage.

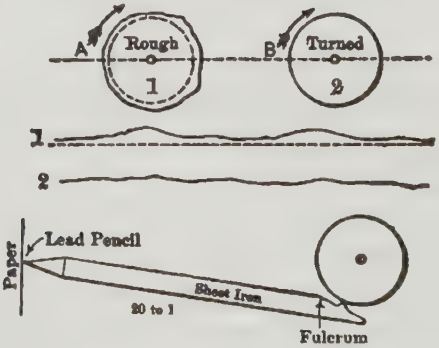


Fig. 87.—Device for Testing a Turned Surface.

It will be interesting to note at this point what really takes place in turning, as shown in diagrammatic form, exaggerated, in Fig. 87. Here is represented a piece of rough

stock that is to be turned as indicated at the right. Starting at A, and developing the line of circumference in a straight path, we will get a line like (1). After turning, and repeating the process, the developed line will look like the line at (2). It will be noted that the second line is somewhat irregular, showing that even after roughing off, the surface of the piece has nearly all of the irregularities of the rough stock, though on a smaller scale.

The bottom figure in the sketch illustrates the tool and method of obtaining the lines. A long, light lever has a knife edge or point at one end, near the fulcrum, which bears against the periphery of the work. On the other end is a lead-pencil attachment, the point bearing against the piece of paper indicated, the paper traveling at the same rate of speed as the work, in the direction of the axis of the work. Any unevenness in the surface of the work raises or lowers the point of the pencil and, as the ratio is great (20 to 1), the variation of the line is marked.

This emphasizes also another important point, and that is the necessity of centering work as accurately as possible, for, no matter how even the work may be on its circumference, if centered out of true it will not be round after turning. Why? Because the thickness of the chip or shaving is not uniform, hence does not offer uniform resistance to the cutting edge, and the work will bend more, and the tool will spring more, at one point than at others. If the cut were uniform in depth, thus giving the same resistance, of course we could expect round work.

54. Angle of the Tool to the Work. Next in importance to the leverage of the tool is the angle at which it is set in relation to the work. Referring now to Fig. 88, the tool is shown at right angles to the work, and any deflection would move it away from the work, instead of causing it to gouge into the work.

55. Height of the Tool. The third point to be observed in regard to setting the tool is its height relative to the lathe

centers. In Continental shops, and especially in England, it has become a recognized principle that the top of the cutting edge of the tool should not be higher than the top of the support, and to obtain its top rake the tool is harrowed

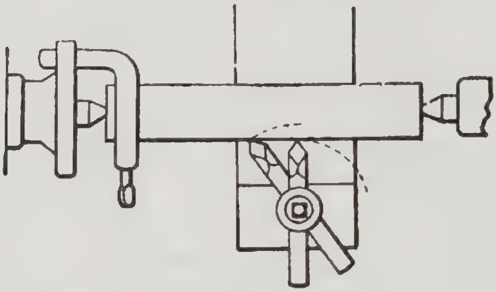


Fig. 88.—Angle to the Work.

out in grinding. Sir Joseph Whitworth designed his lathes so that the tool support was at the level of the center of the work, and any vertical pressure deflected the tool away from it, as shown in Fig. 89. Fig. 90 illustrates three positions of the tool. Tool No. 1 is set below the center, and the dotted line, drawn tangent to the periphery of the circle

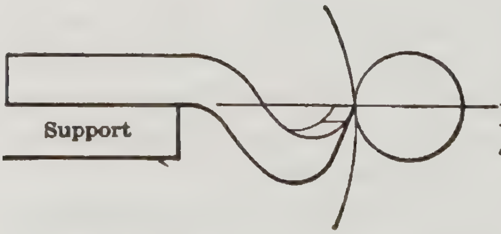


Fig. 89.—Tool at the Center.

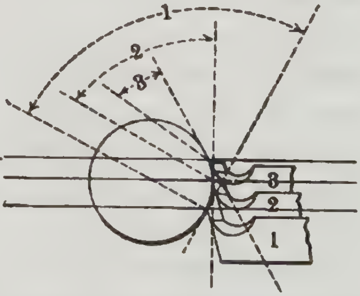


Fig. 90.—Setting Lathe Tool to Correct Height.

at the point of the tool, indicates the direction in which the cutting force is applied. The top or cutting surface of the tool forms an angle of 90° with this line. The stock is thus merely crowded off by the tool and there is no cutting

or wedge action whatever. The next tool is set on the center and has more of a wedge action, but still not what it should have. The top tool, No. 3, gives us a better position for doing maximum work with minimum resistance. In this position the front of the tool below the cutting edge is almost tangent to the new surface which the tool is forming on the work.

From the foregoing it is seen that the lathe tool will do the best work when held very short, at right angles to the work, and when set above the center. This will lead to economy.

56. Grinding Tools. The diamond point tool should be ground only on the top, and the angles of the sides should never be touched; there will be no danger then that you will destroy the economic value of the tool. Many mechanics burn, or draw the temper of, the cutting edges of the tool in grinding, which makes the edge softer than the metal it is supposed to cut. In large modern shops the practice frequently obtains of grinding lathe and planer tools upon a special grinder and issuing them to the mechanics as needed, dull ones being turned in for re-grinding. This insures uniform, expert grinding, and economizes the time of the men.

Reference has been made thus far entirely to the solid tools most commonly used. But there are many improved tool-holders in use, designed for self-hardening steel, which is not affected by burning in the hands of incompetent mechanics, either in grinding or through lack of knowledge of the proper cutting speeds. These holders support the steel in such a position as to give the proper front and side clearance, and the rake is determined by the grinding, as as in the case of solid tools.

57. Rake and Clearance. Referring to Fig. 91, the rake and clearance of lathe diamond-point tools will now be considered. The angle of clearance, sometimes called the angle of relief, as indicated here, is about 7°, sometimes

running to 10°, more or less—enough for a safe working angle. Really the only reason for so much clearance is to avoid rubbing against the cut surface, which would cause unnecessary frictional resistance to the motion of the lathe and compel a change in the setting of the tool for every change of diameter in the work. Efforts should be directed toward finding the angle that will give the least force required for cutting, combined with endurance of the tool edge.

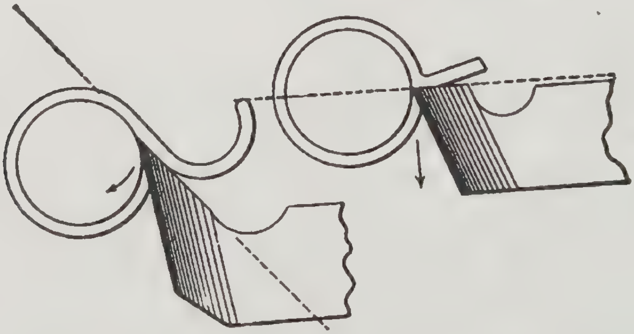


FIG. 91.—Too Great or too Little Rake.

While the power required to cut is increased greatly by the dullness of the cutting edge, the wood-chisel edge should be avoided, because time lost in constantly removing the tool for grinding purposes eats up profit. In Fig. 91 are illustrated two extreme cases—that on the left having too great rake, and the other having none. The one will do good work for a few minutes provided the cut is not too heavy, but the wear of the edge is so great that the angle will soon become blunt, and it would be very much better to have no rake at all. On the other hand, the cutting edge of the tool on the right is too blunt to do good clean work, and the chip will come off nearly straight and in small pieces. The happy medium between the two is found in Fig. 92.

Side rake means the angle at which the top is ground either to the right or left side. A tool ground for a travers-

ing motion toward the left hand cannot be used with a motion toward the right. Therefore side rake is designated right-hand or left-hand, the former meaning that it has its cutting

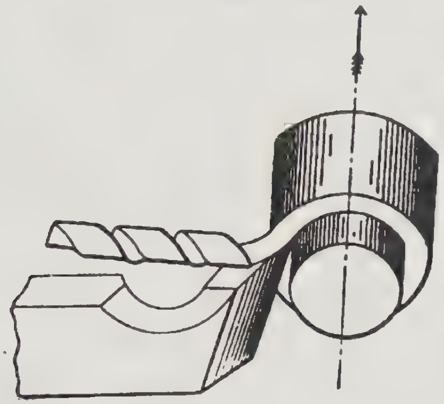


FIG. 92.—Proper Rake.

edge on the left side and the latter on the right side. As the side rake is increased, the power to drive the tool becomes less, as it tends to screw its way along. *Back rake* means the angle given to the top of the tool from the point back. *Rake* or *top rake* may mean back rake, side rake, or both.

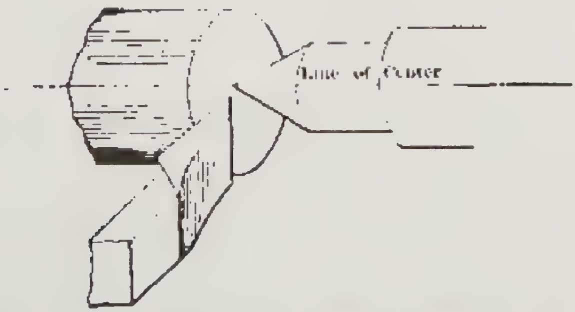


FIG. 93.—Proper Position for Side or Facing Tool.

The round-nose tool, Fig. 84, is used for brass when made rather pointed, and for facing cast iron, when it has a blunt point. The tendency with brass, which is very soft, is to

pull a hooked tool into the work, hence no rake can be given the tool.

The side tool should always be set with the point leading slightly, but one must remember that it is not the point, but the side of the tool that is to do the cutting. This tool should be set on the center, as indicated in Fig. 93, and has side rake only.

58. Centering Tool. The centering tool is used to obtain an accurate center for starting a drill, and should

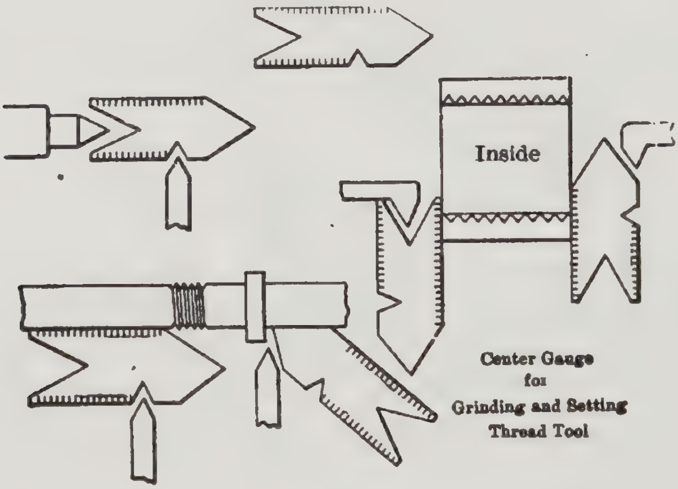


Fig. 94.

be ground like a twist drill and placed with its cutting point directly at the center of the work.

59. Thread-cutting Tool. Much carelessness is exhibited in the use of the thread-cutting tool, not so much in grinding as in setting. It should be set so that the cutting edges make equal angles with the line of lathe centers. The economical way to use this tool is to rough out the thread with a heavy cut, regrind the top face until again sharp, and then finish with a light cut. No matter how carefully a thread tool is used, the point will wear rapidly. This tool should have no rake when making the finishing cut.

Fig. 94 shows the manner of setting thread-cutting tools under differing conditions.

60. Cutting-off Tool. Fig. 95 refers to the cutting-off tool, the last of the lathe tools shown in Fig. 84. The upper view shows the action of the tool, and the two lower views indicate how good and poor results may be obtained through grinding. This tool has side clearance right and left, and should be ground slightly concave, and with back rake, on its top face. Its point should be on a level with the center of the work.

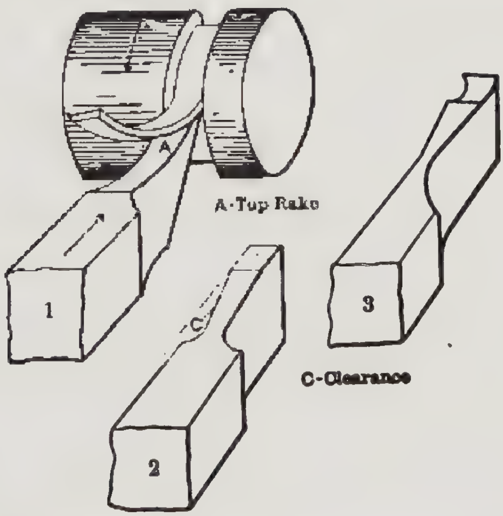


Fig. 95.—The Cutting-off Tool.

61. Tool-holders. Fig. 96 shows a number of types of patent tool-holders, already referred to, which are common in the modern shop because they are more economical for use on ordinary sizes of work. For very large work, however, the solid tool is more economical on account of its rigidity, which is not always obtained in the built-up holder. Competition has forced the use of any appliance whereby a saving may be made, and in the case of the tool-holders the amount of money tied up in tool steel is reduced

to a minimum, which is not the case when solid tools are used. The saving is made in two ways, the cutting edges do not have to be forged or redressed by the smith, and a more uniform angle of rake is maintained.

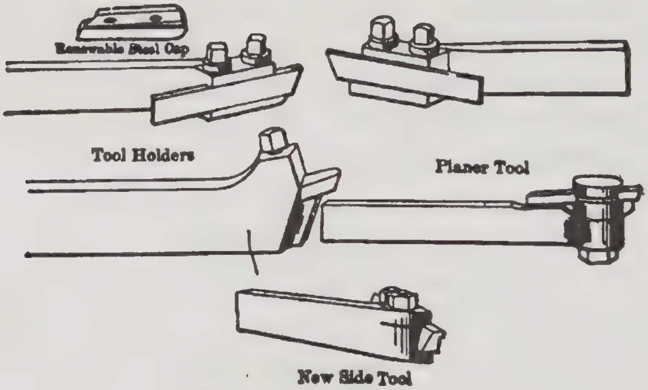


FIG. 96.—Tool-holders.

62. Lathe Speeds and Feeds. The accompanying table gives the finishing speeds and feeds for different metals for tools of ordinary tool steel. In roughing, the axiom is, slow speed and quick feed; in finishing, high speed and

LATHE CUTTING SPEEDS AND FEEDS

FOR CARBON STEEL TOOLS

Tool Steel	Wrought Iron Machine Steel	Cast Iron	Brass
$S : F$	$S : F$	$S : F$	$S : F$
28 : 25	40 : 20	48 : 16	120 : 20
Lubricated	Lubricated	Dry	Dry

F = number of revolutions to 1 inch of feed.
S = number of feet per minute.

HIGH-SPEED TOOLS

Tool Steel	Wrought Iron Machine Steel	Cast Iron	Brass
$S : F$	$S : F$	$S : F$	$S : F$
38 to 45 : 20	65 to 75 : 12 to 20	60 to 70 : 12	180 to 200 : 20
Lubricated	Lubricated	Dry	Dry

fine feed. From this table about 25 per cent should be deducted for roughing speed, making 18, 24, 28, and 83. Experiments on cutting tools made in the shops of R. H. Smith, London, England, and verified by the author, show that machine steel requires from two to two and one-half times as much power for cutting as does cast iron, and wrought iron, about one and one-half times the power.

CHAPTER X

CUTTING TOOLS—(*Continued*)

Difference between rake and clearance of turning and boring tools. Different methods of holding work. Boring tools. Deflection. Cantilever principle defined in boring tool. Improved types of holders and their economic value.

The previous chapter is confined entirely to one class, namely, planer and lathe tools, and the different conditions under which the best results can be obtained from them. By best results is meant the maximum amount of good work with the minimum amount of energy expended, the ideal for which every good mechanic is striving. The cardinal points for securing these results were discussed, such as proper back and side rake, clearance, rigid setting, locating the tool so it will not spring into the work, proper relation of cutting wedge to plane of work, etc. All these combine to make the cutting edge the basis of economic production, and economic production means not only least cost in manufacture, but a saving in the wear and life of the machine.

63. Inside and Outside Turning Compared. The subject of cutting tools has purposely been divided into two separate heads, as there is a recognized distinction between inside and outside turning; Fig. 97 shows that the same laws do not hold for both. The circle on the left represents a cylinder to be turned; that on the right, a hole to be bored, with the tool in position. The lines *ab* and *cd* are drawn tangent with the work at the point where the cutting edge is in contact with the work when turning and boring respectively. On the face of it, it would seem that one vertical line should answer for both conditions, but this is not so,

for in turning, the cutting edge of the tool may be set above the center of the work, thus obtaining a finer cutting wedge. The angle A is the angle of the cutting wedge in turning, while B is the angle of the cutting wedge in boring. This is the best condition obtainable in boring, but it is not as good as could be desired.

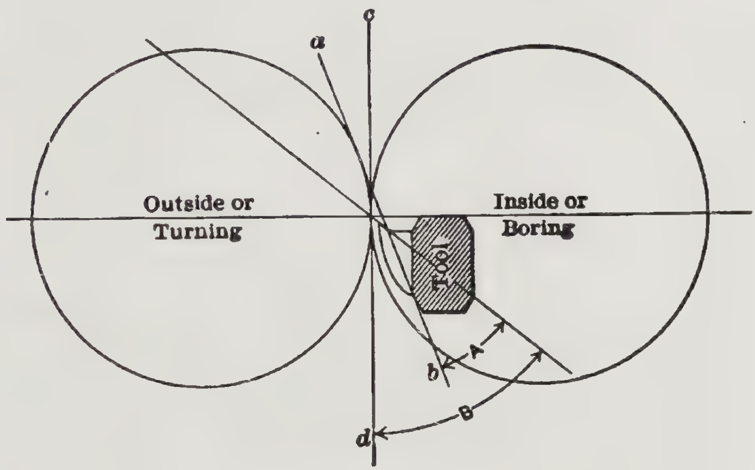


Fig. 97.

64. Rake and Clearance for Inside Turning. The rake and clearance of a tool for inside turning must be different from that used for outside turning, for two reasons: First, because of the contracted and peculiar conditions under which the boring tool works, and second, because of the spring of both tool and work-conditions met with in boring which do not apply in outside turning. The spring of the work is overcome in many cases by using a steady rest to support one end of the work, while the other end is held in the chuck, or clamped to the face-plate and supported by the live center itself. In the latter case it must be laced to the face-plate. Fig. 98 may offer a suggestion to those who find difficulty in keeping the work tight against the center. It shows the face-plate partly unscrewed. The lacing is made fast to a dog or carrier in that position,

and the face-plate is then screwed up in place, thereby tightening the thong.

65. Setting the Steady Rest. Unless great care and skill are combined in setting the steady rest in position, the result will be a failure because, in boring, the object is to get the bore concentric with the outside, and it is a very easy matter to defeat this object by careless setting of the rest. A suggestion as to the way of setting it may here be in order. If the work has already been turned on the outside, the centers may be used to good purpose. Keep the

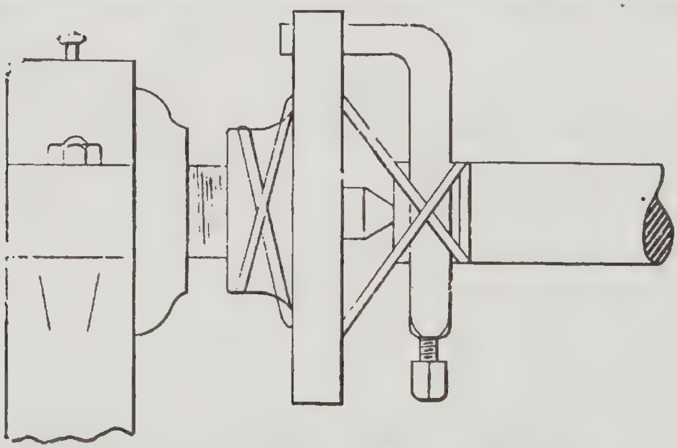


Fig. 98.—A Suggestion for Keeping Work Tight.

live center in the lathe spindle, screw the chuck in position and put the work on the centers as for ordinary turning. Now carefully tighten the chuck jaws upon the work, and then place the rest in position at the dead center end and adjust it, the work all the while being on the centers. The rest is then opened, the chuck with the work in it is unscrewed, and the center removed. Where this method can be used, it will insure accuracy.

If it is a rough piece of work which is to be set, support one end by the dead center, turn a true surface for the jaws of the steady rest, and place the same in position while the work is still on the center.

66. Reason for Tapering Bores. While lathes are adjusted so they will never bore a hole larger at the back than at the front, the tendency is to make this adjustment so the lathe will bore very slightly smaller at the back; another reason why bored holes are frequently a little taper-

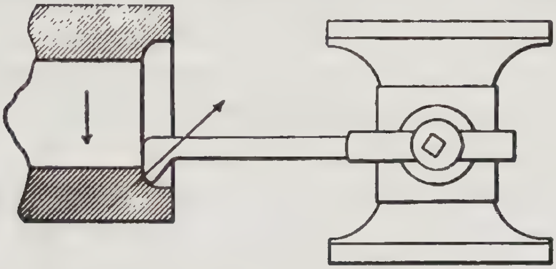


FIG. 99.—Cutting Action of Boring Tools.

ing. Do not decide, however, that it is the fault of the lathe if the hole is not straight; look to see whether the lathe is properly leveled up, and whether the four legs are properly bedded. Very often the builders are blamed for poor work, when the real fault is that the conditions are not

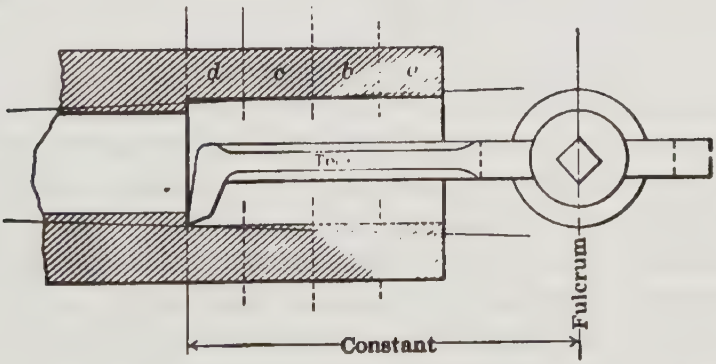


FIG. 100.—Boring Tool—Old Type.

right. If the legs are not properly set there will be a wind in the shears of the lathe which will defeat good turning or boring.

67. Boring Tools. Fig. 100 shows an old-fashioned boring tool of the type common in every shop, and Fig. 101

shows several of the more usual tools for boring and thread-cutting. These tools are forged by the tool dresser in lengths, and sizes that will cover a wide range of work, so that different diameters and depths may be bored without re-dressing. As to results from this type of tool: When the tool starts its cut there is a downward spring which we call vertical deflection, due to the pressure of the chip on the top of the tool. This pressure is nearly constant throughout the entire length of the cut, and does not vitally affect

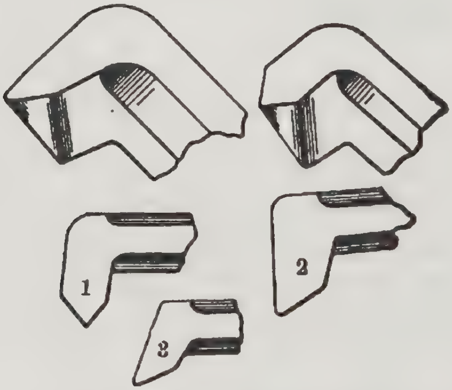


FIG. 101.—Types of Boring Tools.

the accuracy of the work, since there can be a slight vertical movement of the tool without appreciably changing the diameter of the hole being bored. This is not the case, however, with the lateral pressure on the boring tool, which pressure, being at right angles to the cutting edge, deflects the tool away from the work more and more as the cutting edge dulls, thereby changing the angle of motion of the tool constantly. The result is a conical hole, and much time is lost in taking repeated cuts to get the bore parallel.

This type of tool, therefore, does not prove economical, although the outward or lateral pressure will vary somewhat with the shape of the tool and the way in which it is dressed. If the front or cutting edge makes an acute angle with the

work, the lateral pressure is considerable; but if the cutting edge is at right angles to the work there is less tendency to deflect the tool in a sidewise direction. In the latter case, however, as the cutting edge wears away and the tool becomes dull, there is a tendency for the corner to become worn so as to form an acute angle, and we will have some of the same trouble to contend with. Theoretically and practically, a tool ground as in Fig. 101 (3) will give the best results, so far as cutting is concerned, but even by using the greatest care and judgment in dressing and grinding the tool, to reduce sidewise deflection, we cannot altogether remove the difficulty.

The question of deflection is largely one of leverage. The amount of deflection will depend upon the length of the tool from the binding screw in the tool-post to the cutting edge. After a tool is once made, its leverage is always a constant quantity, since the tool must always be placed in approximately the same position in the tool-post. It will therefore deflect as much in boring a short hole as in boring a long one, assuming the cutting edge to be in the same condition in each case. The longer the tool, the greater the deflection, for the tool is a cantilever, the deflection of which is increased eight times when its length is doubled. From this, we can readily see how important is this consideration of leverage, and how desirable it is to have the boring tool adjustable, so that it need project from the point of support only as far as is necessary to bore the full depth of the hole required. The mechanic should try to overcome this difficulty by devising ways and means for making the tool adjustable; many schemes are open to him.

68. Boring Tool Holder. Fig. 102 will give an idea for a tool holder and for different tools which are inexpensive and at the same time meet the requirement stated in the preceding paragraph. This holder gives at all times the greatest rigidity and allows the use of the largest size of tool possible for any particular work. It also enables the operator

to vary the leverage to suit each particular hole. The holder consists of a rectangular block of cast iron through which two holes are bored, one on each side of the center, close to the edges, and on a plane with the lathe centers. After these holes are bored the block is sawed in two through the center of the holes, the top forming a cap. The holes may be made any standard size, $1\frac{1}{4}''$, $1\frac{3}{8}''$, $1\frac{1}{2}''$. Into these holes are fitted sleeves, or the drill rod itself, although the use of sleeves gives a wider range of sizes of boring tools

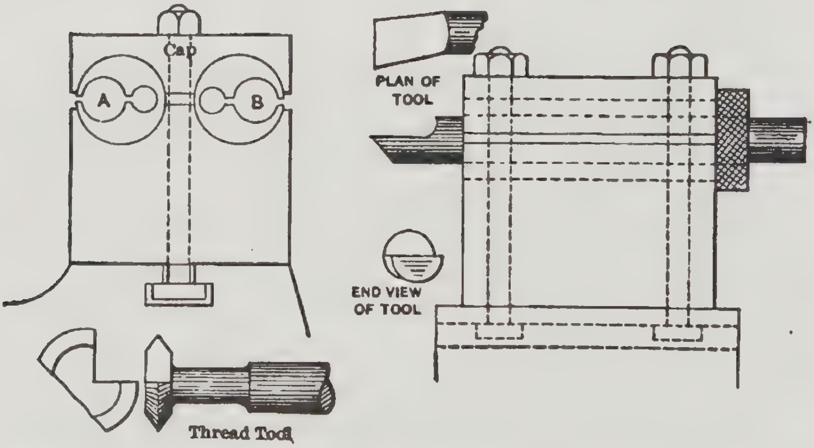


Fig. 102.—Boring Tool Holder and Type of Inside Threading Tool.

for each holder, by having a number of sleeves with different standard size holes. Fig. 102 shows the holder with sleeves inserted. The tool fits in either *A* or *B* of the sleeves. If the tool is to be used in *A*, a solid piece is inserted in *B*, so as to give a support against which to clamp the cap. One end of the sleeve is knurled to allow the thumb and finger adjustment in raising and lowering the tool. Ordinary drill rod is used, filed down to a flat surface at the end as shown. When heating for the tempering process, set over the filed end by a blow of a hammer to give clearance. One advantage possessed by this holder is that a tool nearly

the size of the hole to be bored may be used, thus insuring the minimum of deflection.

A thread tool of the type shown may be used with this holder; in such a tool the plane of the top is sure to be set so it will intersect the center line of the work, which is the requisite for a true thread.

QUESTIONS ON CUTTING TOOLS

1. Give table of United States Standard threads.

2. Give formula for diameter at the bottom of the thread, of United States Standard and V-threads.

3. What is the difference between the pitch and lead of a thread?

4. What proportion of the lead is the pitch on a single thread? On a double thread?

5. Why do you use a lubricant on a fibrous material? What is a good mixture for this?

6. How large is the flat (in terms of pitch) at the top and bottom of United States Standard thread?

7. What combination of feed and speed is satisfactory for roughing cuts, in general?

8. What is the meaning of cutting speed?

9. A piece of stock is 12″ long, and is to be tapered ½″ per foot. How much must the poppet head be set over? Give calculation in note book.

10. What is the best method of finishing work in the modern shop?

11. What sort of a gauge is commonly used for sizing when taking a finishing cut? Describe it.

12. How is a turning tool ground for finishing?

13. Make sketches showing the various tools used on the lathe.

14. If you turn a piece of rough work, will it show any of the irregularities of the rough surface in the finished piece?

15. Why will a piece of work be out of round after turning, if it is not centered true?

16. What is the proper angle of clearance on the lathe tool?

17. What is the reason for a large clearance on the lathe tool?

18. Toward what should our effort be directed in selecting the angles of cutting tools?

CHAPTER XI

BORING MILLS

Vertical and Horizontal

Their functions as productive machines. Construction of table. Difference between the two types of machines. Maintenance of parallelism. Facing attachment.

69. Types of Boring Mills. The boring mill is ostensibly a face-plate lathe inverted. There are two types, the **vertical** and the **horizontal**, shown in Figs. 103, 105, and 106.

In the vertical type of machine the work moves, and the tool is fed against it.

In the horizontal type the work is stationary and the tool, which is carried by either the main spindle or boring bar, or by a tool-head clamped to the bar, has both rotation and feed.

Both machines have a broad field of usefulness and are classed as cheap-production machines, because of their adaptability to jig and fixture work.

70. Difficulties to be Overcome. The life and accuracy of a lathe depends largely upon its main spindle, and unless the head stock is made very large the size of the spindle must of necessity be limited. In clamping work on the face plate of a lathe for purposes of boring, as the size and weight of the work increases, the difficulty of setting and securing it in place becomes more involved, but aside from this there is also the weight of the enormous overhanging parts, which increases the friction on the journal bearings,

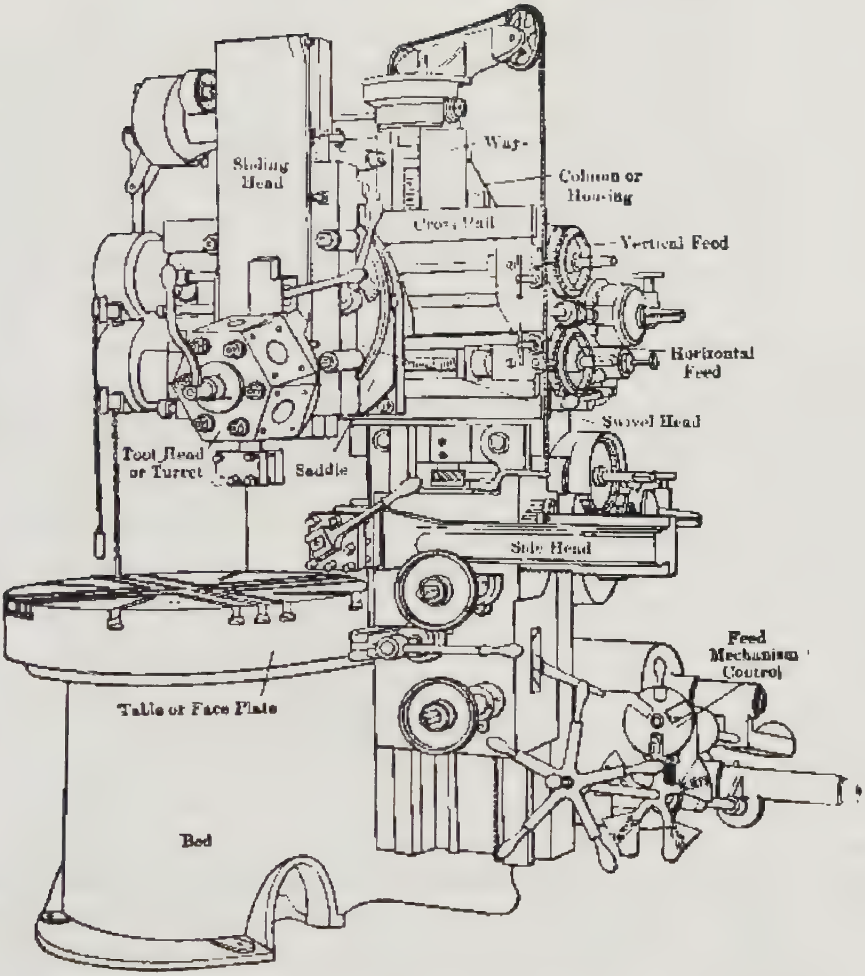


FIG. 103.—Bullard Vertical.

Bed (C. I.)	Liner for wear (Babbitt or bronze)	Table (C. I.)	Work				
	Column or Housings (C. I.)	Ways (C. I.)	Cross rail (C. I.)	Saddle (C. I.)	Sliding head (C. I.) Swivel head (C. I.)	Turret or tool head (C. I.)	Tools
		Side head (C. I.)	Tool box (Cru. steel)	Tool (T. S.)			
		Feed mechanism and control, (C. I. and steel)					

creating rapid wear. The increased vibration as the weight increases must also be contended with.

71. Vertical Boring Mill. In the construction of the vertical boring mill these difficulties have all been eliminated; an increased size of bearing is possible and it is so designed that the table has a self-centering tendency, a very important consideration. The work is easily clamped or chucked in position with less loss of time, and the multiple-head construction makes it possible to still further cheapen production by having a number of tools operating at the same time. Fig. 104 shows the large angular-bearing construction of the table, with the method of oiling and driving, etc.

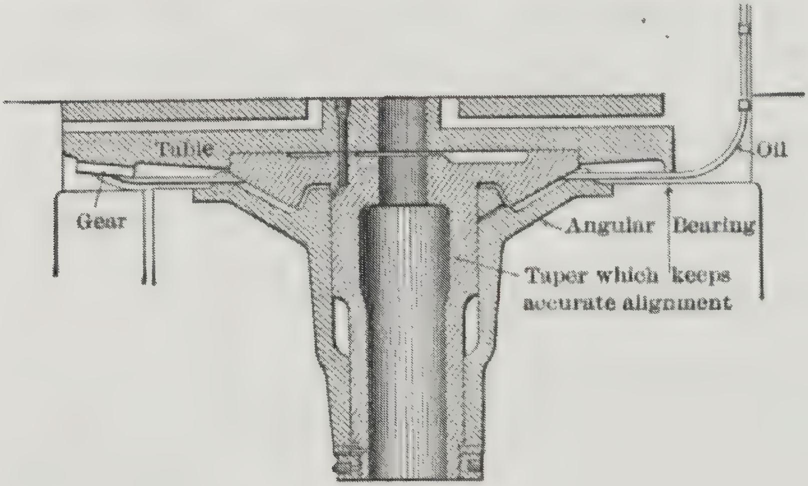


Fig. 104.

These machines are designated by the size of the table, as for instance a 30-inch mill has a table 30″ in diameter. The smaller mills are made with single housing which carries the cross-rail; the sizes above 36″ are made with double housing similar to that of a planer, and connected with a top rail. These machines carry a multiple tool, head or turret capable of holding a complete set of tools for finishing a job.

As a manufacturing machine the vertical boring mill is ranked among the foremost. It is more easily adaptable to jigs and fixtures than the old type of face-plate lathe, and can be run at a higher rate of speed and with heavier feeds, due to the perfect balance of its rotating parts.

72. Horizontal Boring Mill. The horizontal boring machine is built on two distinct principles of construction or machine design. In one the bar, which is carried in a sliding head on an upright housing, as in Fig. 105, is raised or lowered to suit work conditions. In the other, the work is raised or lowered to suit bar conditions, as in Fig. 106. The important thing in each machine is to maintain parallelism, and when the platen is moved, as in Fig. 106, by means of the elevating screws, unless the knee is gibbed light and is at right angles to the ways to start with, the tendency to shift the level of the platen each time it is moved is inherent. On the other hand, any change in the outboard bearing bushing, Fig. 105, wherein it does not move accurately with the bar movement, is open to the same criticism.

73. Special Types. Special forms of horizontal boring machines are in use for specialized product, such as frames for railway motors, cylinders for locomotives, etc. Where both faces of the cylinder can be machined at the same time by means of the facing head attachment, as illustrated in Fig. 107, a device for clamping on the main bar or face plate of the machine performs the same function as the slide rest on a lathe when the tool post moves along the ways.

The tool post traverses the entire length of the ways by means of the screw *A*, and these ways, being at right angles to the plane of the bar, face the cylinder head. The feed is the primitive star-wheel feed, which is at least fifty years old, having been used on the old type lathes which did not have power-feed attachments. The principle of its operation is rather ingenious, as the amount of feed

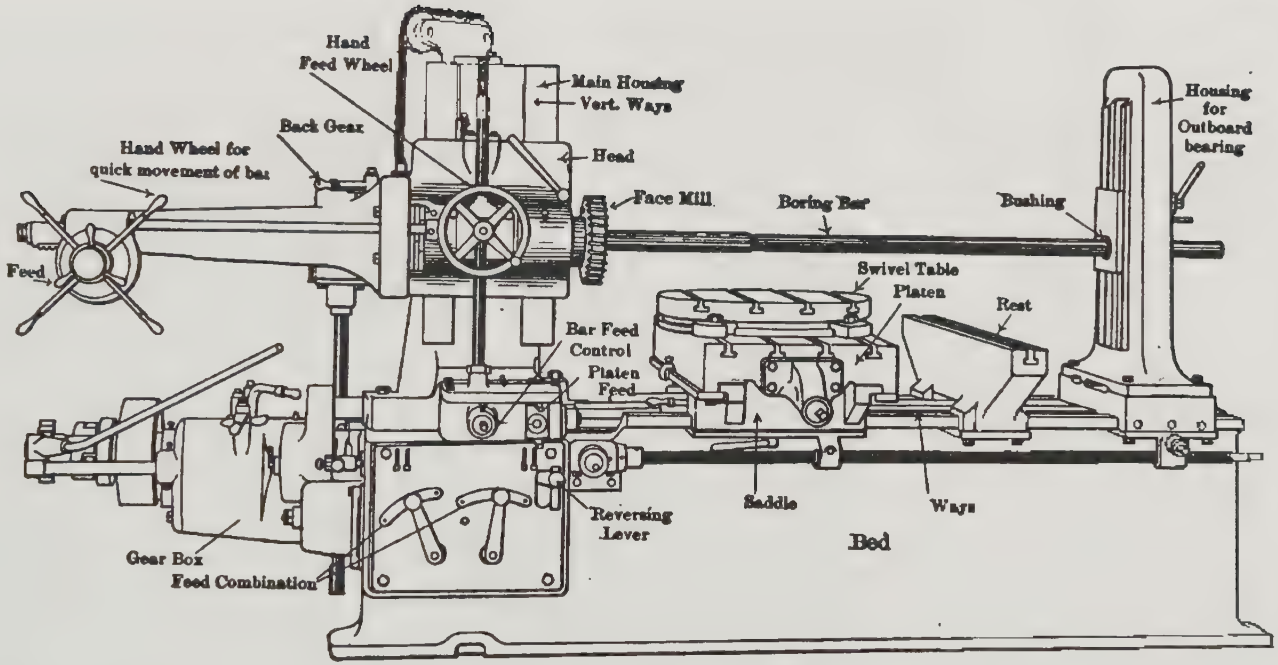


Fig. 105.—Lucas Boring Machine (Cleveland).

Bed (C. I.)
- Column (C. I.)
  - Head (C. I.)
    - Main spindle (Cru. steel)
      - Boring bar (Cru. steel) or cutter (T. S.)
  - Spindle bearing (C. I.)
    - Rack and pinion (C. I.)
- Ways (C. I.)
  - Saddle (C. I.)
    - Platen (C. I.)
      - Work
- Housing (C. I.)
  - Bushing for outboard bearing (C. I., or steel, or bronze)
- Transmission mechanism (C. I. and steel)
- Feed (Cru. steel)

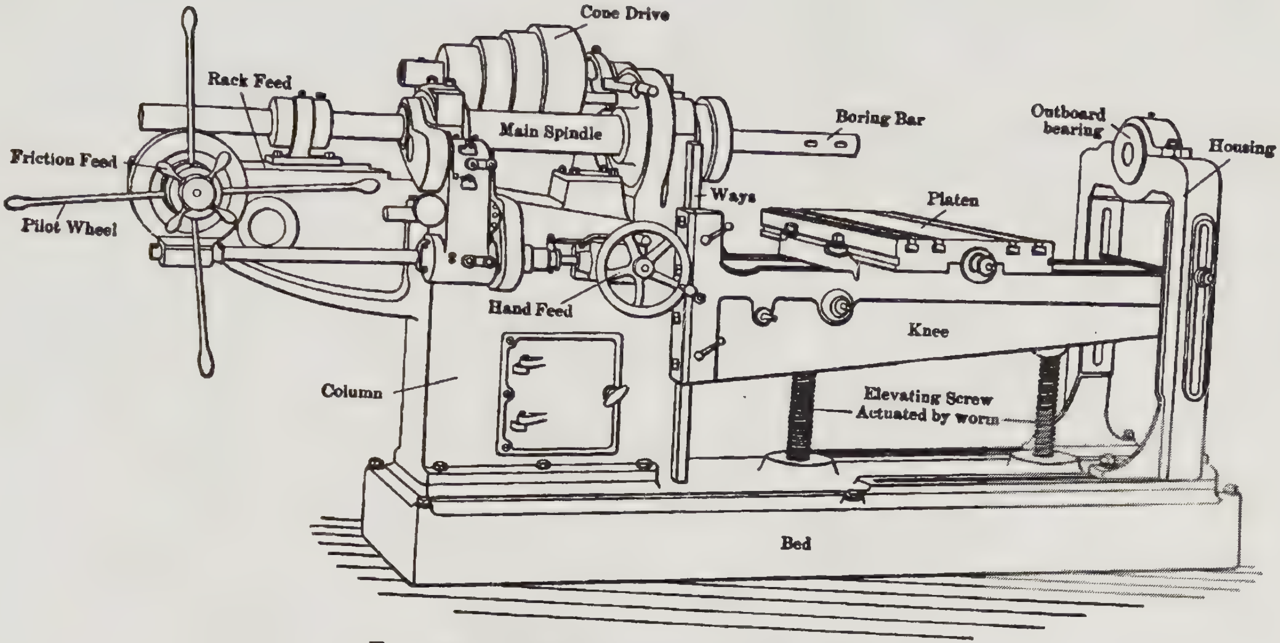


Fig. 106.—Binsse Horizontal Boring Machine.

- **Bed (C. I.)**
  - **Column (C. I.)**
    - Feed mechanism (Cru. steel)
    - Ways (C. I.) | Knee (C. I.) | Platen (C. I.) | Work
    - Main spindle | Boring bar (Cru. steel)
    - Bushing (Bronze) | Cone pulley transmission (C. I.)
  - **Housing (C. I.)**
    - Outboard bearing (C. I. or bronze) | Boring bar (Cru. steel)

can be varied at the will of the operator. As the head X is rotated by the bar, the star wheel comes in contact with a stop pin which is clamped on the bed of the machine,

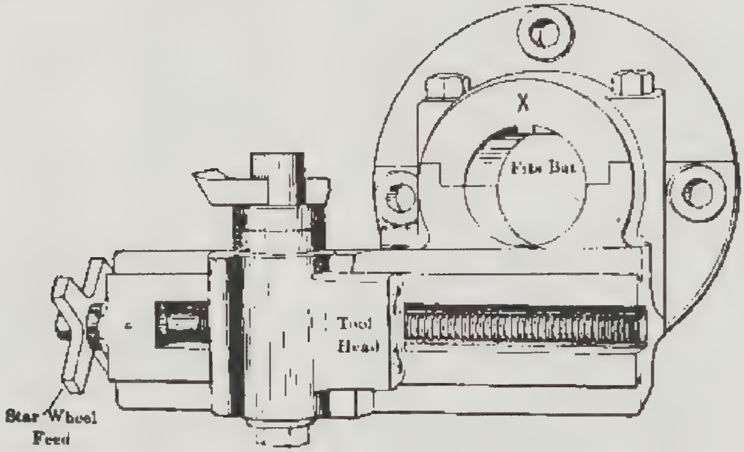


Fig. 107.--Facing Head Attachment.

or which fits in a hole designed to carry it; one of the points of the wheel strikes on this pin, rotating the wheel, which in turn rotates the screw which actuates the tool.

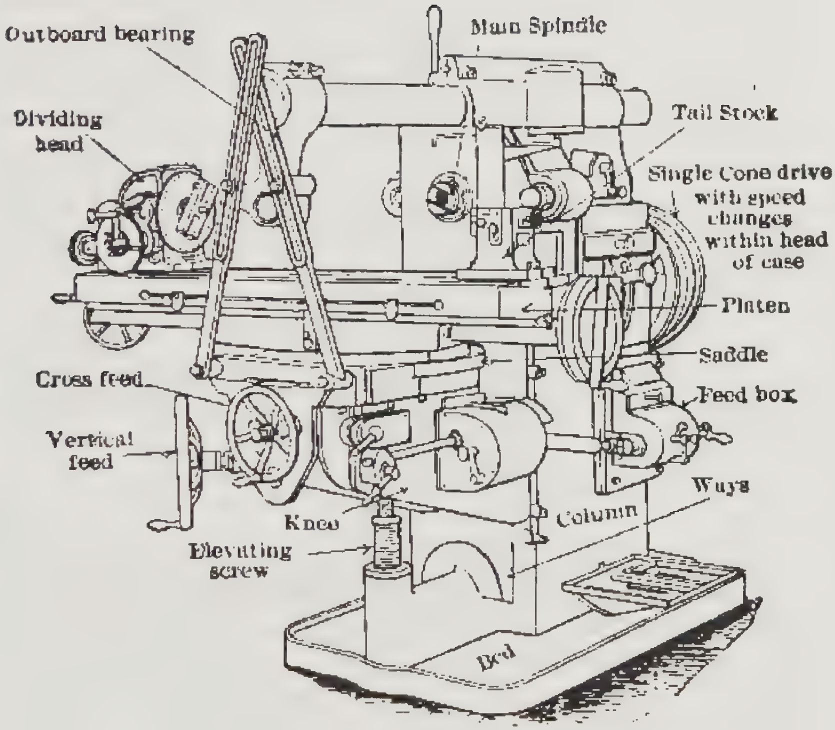


Fig. 108.

Milling machines and the relation of parts to each other.

Base	Column	**Knee**	**Saddle**	**Platen**	**Dividing head**
					Tail stock
			Support for outboard bearing		
		Cone pulley			
		Back gears			
		Main spindle	Arbor	**Cutter**	
				Collets	
		Feed mechanism		**Nut**	

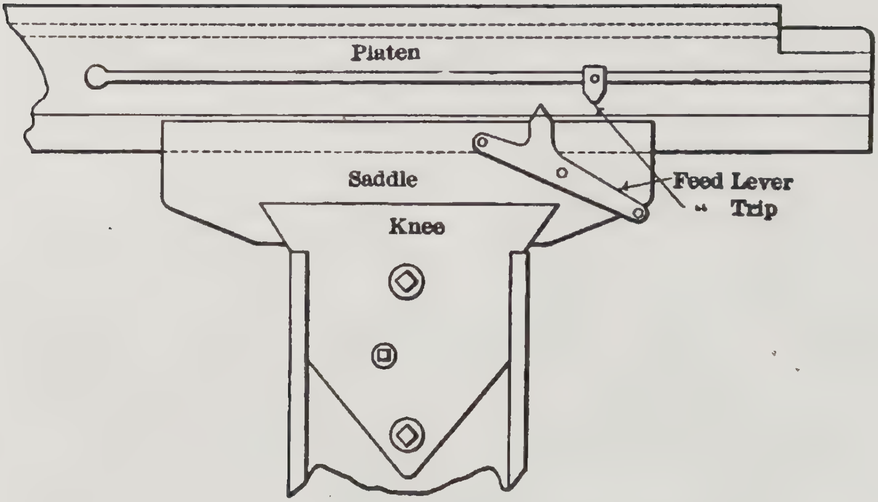


Fig. 109.—Construction of Plain Milling Machine.

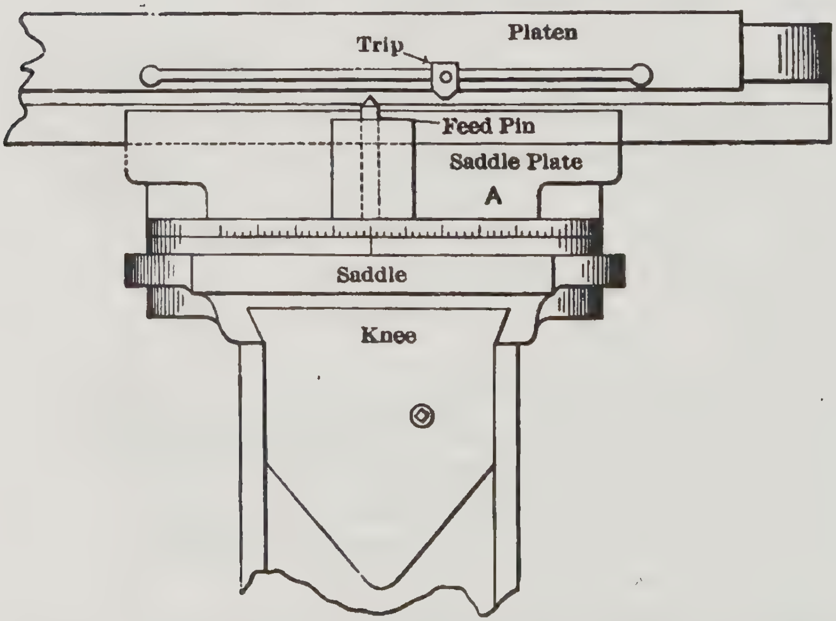


Fig. 110.—Construction of Universal Milling Machine (Brown & Sharpe.)

75. Types. Milling machines are designated either as **plain** or **universal.**

Fig. 109 illustrates the type of construction of a plain milling machine. It will be seen that the platen cannot be changed from its right-angled position; hence this machine is not available for spiral milling.

Fig. 110 illustrates the type of construction of a universal milling machine, with compound saddle, which enables the platen to be swung to any desired angle to give cutter clearance for spiral work.

76. Parts of Milling Machine. The **column** is the main casting upon which the **knee** travels up and down.

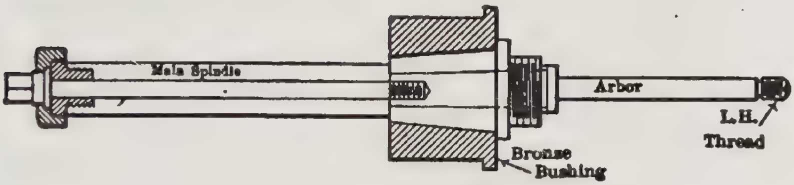


FIG. 111.

On this knee is supported the **saddle,** which gives the in-and-out feed movements; the saddle supports the **platen,** which gives the traversing feed, and on the platen rides the **index head** and **tail stock,** both of which have centers upon which the work is supported.

On all the feeds or screws used to give motion to the work are discs graduated to read in thousandths of an inch, insuring great accuracy.

Of the other parts, the first important thing to study is the **arbor** which carries the milling cutter. It is designed to fit into the taper which is bored in the front end of the main spindle of the machine; see Fig. 111. There are no recognized standard tapers for these arbors, different makers having their own individual standards. The arbor should fit perfectly in its socket, and should have a key, also, not relying on the friction alone to drive without slipping.

The arbor is also supported on the outer end by the outboard bearing which slides along the overhanging arm.

The arbor is drawn into place by a long rod which runs through the hollow spindle of the machine. This rod has a collar, as in Fig. 111, which beds against a sleeve threaded into the back end of the main spindle, Fig. 112; this sleeve being thus constructed for the purpose of removing the arbor by screwing in against the collar.

The arbor is ground to some standard size, according to the size of the machine it is intended for, $\frac{7}{8}''$ or $1''$ diameter. The nut on the arbor has a left-hand thread in order that the cutting resistance may tighten rather than loosen it, which would be the case were it right-handed; see Fig. 113.

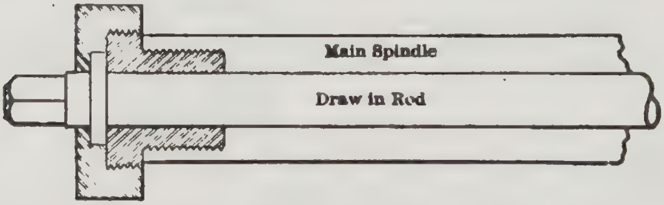


Fig. 112.

Collets of varying lengths are made for the purpose of spacing the cutters, and also to act as washers for holding the cutters tight. The cutters should also be held by a key to keep them from rotating, not relying on the frictional hold of the collets. The varying lengths of the collets are for use in gang milling, to space the cutters, as in Fig. 113.

It is very important that the ends of these collets should be faced true and parallel, and at right angles to the bore, the edges being rounded as in Fig. 113, because the rounded edges lessen the possibility of the faces becoming burred. This is very important, for these collets are among the most important attachments of the milling machine; no matter how well designed or how powerful the machine may be, carelessness in this particular will surely defeat good work.

The question naturally arises: Why is so much emphasis laid on these collets? And it is now answered by another question: What is the advantage of having a cutter with, for example, 32 teeth, unless every one of the 32 teeth performs an equal part of the work? This is only possible when the arbor runs perfectly true, and to insure this the collets must also be true, with no dirt or burr on their faces; if there is, when the nut is tightened the arbor will bend,

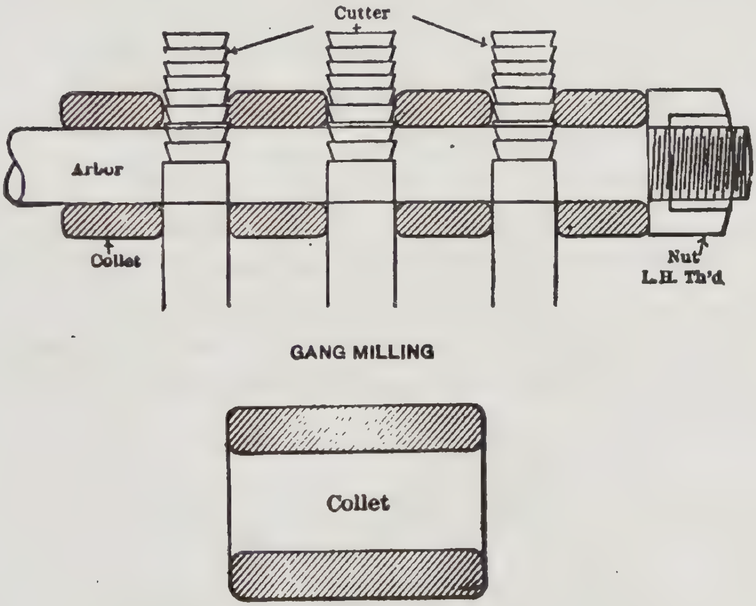


Fig. 113.

with the result that it and the cutter will run out of true, cutting only on the high side, with but few of the teeth.

The milling cutter should be located on the arbor as close to the column or main casting as the work permits, so that as short a leverage as possible is secured, and the outer bearing should be brought as close to the cutter as possible and yet clear the work.

The many cutters and their uses will be considered later. We shall now take up the index head, the most important and complicated attachment of the milling machine.

77. The Index Head. In examining the construction of the index head, Fig. 114, it will be noticed that the housing is graduated in degrees, which indicates at once that the

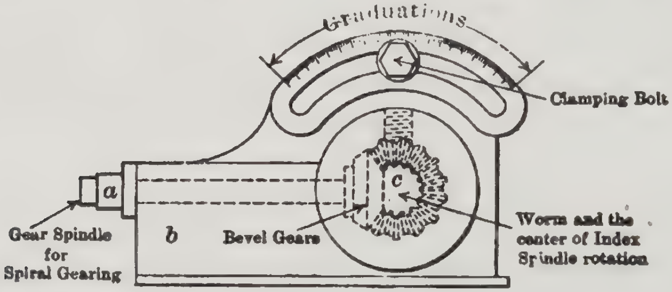


Fig. 114.—Index Head.

head can be swiveled to any angle for taper work of any kind. The method of clamping the head in any desired position is by means of the bolts on either side.

After using it in any position out of the horizontal, it is not wise to rely on the graduations in bringing it back

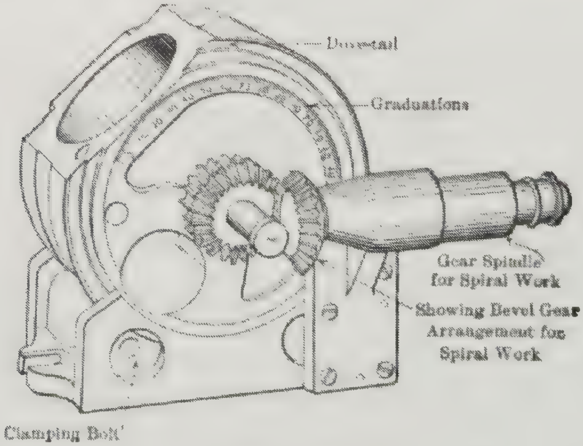


Fig. 115.

into place, for it is difficult to set two lines together by the eye, such setting being at all times only an approximation; nor can it be set by pushing the tail spindle up to it and

again relying on the eye. A straight cylinder, either cast iron or any other material, should be put on the centers, and raised toward the cutter, and the contact felt with a piece of heavy paper such as an ordinary envelope, about .004″ thick. Then reverse the cylinder and repeat the operation of calibrating with the paper; in this way great accuracy can be obtained.

The mechanism of the index head is so arranged, through the medium of the worm and worm wheel, that the index head spindle and the work it carries can be rotated, so that

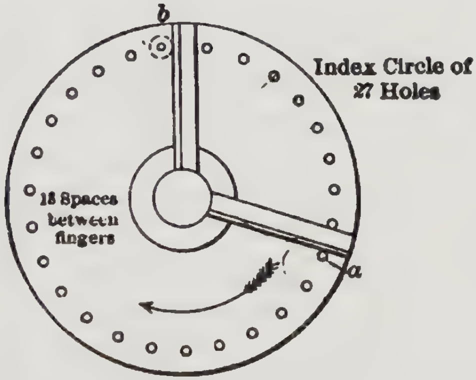


FIG. 116.—Six turns past *a* and up to *b*, 18 more holes.

any part of the working surface, square or round, can be operated upon. There is a definite ratio between the worm and worm wheel of 40 to 1; that is, 40 turns of the crank, which operates the worm, will rotate the worm wheel once. As the worm wheel is fastened to and travels with the spindle of the head, the spindle is thus revolved once.

In using the head, after one side of the work is cut, lower it away from the cutter far enough to insure clearance in turning the work. Then pull the crank of the head toward you, out of the hole, being careful not to change the position of the fingers. Do not turn the crank beyond the stopping point, because, in running back, any lost motion

in the head will defeat accurate dividing; always stop between the last two holes and gently push to the required stop hole; the pin of the crank will then spring into place and hold it as indicated in Fig. 116.

INDEX TABLE

Number of Divisions.	Number Holes in Index Circle.	Number of Turns of Crank.	Number of Divisions.	Number Holes in Index Circle.	Number of Turns of Crank.
2	any	20	35	49	$1\frac{7}{49}$
3	39	$13\frac{13}{39}$	36	27	$1\frac{3}{27}$
4	any	10	37	37	$1\frac{3}{37}$
5	any	8	38	19	$1\frac{1}{19}$
6	39	$6\frac{26}{39}$	39	39	$1\frac{1}{39}$
7	49	$5\frac{35}{49}$	40	any	1
8	any	5	41	41	$\frac{40}{41}$
9	27	$4\frac{12}{27}$	42	21	$\frac{20}{21}$
10	any	4	43	43	$\frac{40}{43}$
11	33	$3\frac{21}{33}$	44	33	$\frac{30}{33}$
12	39	$3\frac{13}{39}$	45	27	$\frac{24}{27}$
13	39	$3\frac{3}{39}$	46	23	$\frac{20}{23}$
14	49	$2\frac{42}{49}$	47	47	$\frac{40}{47}$
15	39	$2\frac{26}{39}$	48	18	$\frac{15}{18}$
16	20	$2\frac{10}{20}$	49	49	$\frac{40}{49}$
17	17	$2\frac{6}{17}$	50	20	$\frac{16}{20}$
18	27	$2\frac{6}{27}$	52	39	$\frac{30}{39}$
19	19	$2\frac{2}{19}$	54	27	$\frac{20}{27}$
20	any	2	55	33	$\frac{24}{33}$
21	21	$1\frac{19}{21}$	56	49	$\frac{35}{49}$
22	33	$1\frac{27}{33}$	58	29	$\frac{20}{29}$
23	23	$1\frac{17}{23}$	60	39	$\frac{26}{39}$
24	39	$1\frac{26}{39}$	62	31	$\frac{20}{31}$
25	20	$1\frac{12}{20}$	64	16	$\frac{10}{16}$
26	39	$1\frac{21}{39}$	65	39	$\frac{24}{39}$
27	27	$1\frac{13}{27}$	66	33	$\frac{20}{33}$
28	49	$1\frac{21}{49}$	68	17	$\frac{10}{17}$
29	29	$1\frac{11}{29}$	70	49	$\frac{28}{49}$
30	39	$1\frac{13}{39}$	72	27	$\frac{15}{27}$
31	31	$1\frac{9}{31}$	74	37	$\frac{20}{37}$
32	20	$1\frac{5}{20}$	75	15	$\frac{8}{15}$
33	33	$1\frac{7}{33}$	76	19	$\frac{10}{19}$
34	17	$1\frac{3}{17}$	78	39	$\frac{20}{39}$

78. Compound Indexing. Thus far what is known as direct indexing has been described, and while the description covers most of the work of the index head, there are times when it is necessary to compound the indexing on work where it is desired to make divisions which no circle in the index plate will give.

Brown and Sharpe, in their treatise on the index head, use, as an example, 69 divisions, and very clearly illustrate the method of obtaining them, through compound indexing. It will require 40/69 of a turn to rotate the work 1/69 of a revolution. In this example they use the 23 and 33 circles on the index plate. If the head were moved 21 holes in the 23 circle, it would give 21/23 of a turn. $21/23 = 63/69$, and we desire only 40/69, hence it has moved 23/69 of a turn too far. If now we turn back 11 holes in the 33 circle, we have $11/33 = 1/3 = 23/69$; hence $(21/23 - 11/33) = (63/69 - 23/69)$ or 40/69.

The method of doing this on the head is as follows; The work is turned through 21 holes in the 23 circle, and then turned in the opposite direction through 11 holes in the 33 circle. The movement is made in the ordinary direct indexing manner. The stop pin, which keeps the index plates from rotating when the crank is being moved, is placed in the 33 circle, the crank is pulled out and moved 21 spaces on the 23 circle, numbering them off by means of the fingers. The next movement leaves the index crank in the 23 circle, while the stop pin is pushed out of the 33 circle and the whole index plate moved 11 holes in the opposite direction from that made by the crank. These holes must be counted, the mistake of counting the stop pin hole as one of the 11 being carefully avoided. Count 11 beyond the one in which the stop pin was first placed. It is important in all indexing to remember that the number of holes to be counted is always independent of the one in which the pin is at the time.

In this example we moved the index crank (turned the

work) too far forward, and then moved it back. In some cases of compound indexing we might turn the work the right distance by moving the crank a fractional part of the required amount upon one circle, and the remainder upon another. The circles chosen would, of course, necessarily be such as would indicate fractions which, added, would give the correct amount.

79. Milling Spirals. The difference between the plain milling machine and the universal has already been noted. On only the universal milling machine can spiral work be done, owing, as has been seen, to the construction which enables the platen to be swung to any angle, to accommodate itself to the pitch desired. The turning of the platen to any angle is for no purpose other than for clearance of the milling cutter, and has no connection whatever with changing the pitch of the spiral cut. The desired pitch could be obtained if the platen were left in its right-angled position, but the shape of the cut would be changed.

By the pitch of a spiral is meant the distance the platen (which carries the work) travels while the work is rotated once. Note the construction of the indexing head and see how this compound motion is effected. The small spindle *a*, Fig. 114, extends through the box *b* and carries a bevel gear which engages with another bevel gear; the latter gear is keyed on the shaft which carries the worm *c*. On the opposite end of this same shaft is an extension or bearing upon which a gear of any desired size can be slipped. This gear on the worm shaft engages a gear on a stud carried by a yoke; a second gear on this stud engages the gear on the screw which actuates the travel of the platen.

Four gears, then, are necessary for spiral work, namely, a gear on the worm shaft, first gear on the yoke stud, second gear on the yoke stud, and a gear on the screw which operates the platen, Figs. 117 and 118. The former figure shows the arrangement of these four gears for spiral cutting, and indicates the first gear on the stud (the first gear slipped on)

and the second gear on the stud as the one following it. This is the Brown and Sharpe practice in designating the stud gears.

To select gears for any desired pitch of spiral, it is essential that the lead of the machine platen be known. As indicated in Fig. 117, the gear on the screw and the first gear on the stud are the driving gears, the second gear on the stud and the worm gear being driven. Now, if the number of threads per inch on the screw were 4, knowing

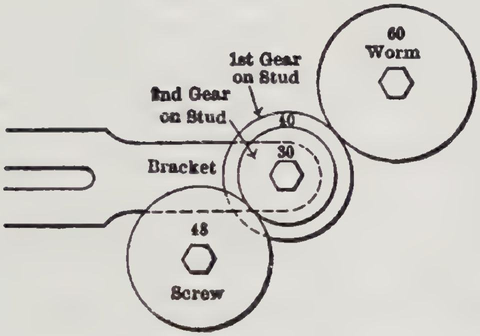


Fig. 117.

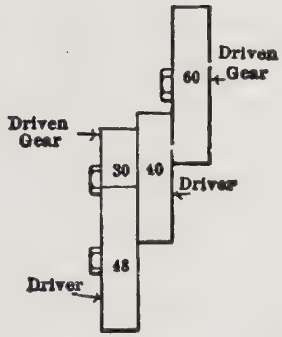


Fig. 118.

Gears for Spiral Work.

that the ratio between the worm and worm wheel is 40 to 1, it is obvious that if all four gears were of equal size the platen would advance 10″ while the index head revolved once. If there were 5 threads per inch on the lead screw, with gears of equal size, the advance of the platen would be 8″. Hence we designate this advance as the lead of the machine. Now, as the driven gears are actuated by the driving gears, and as the pitch of the spiral desired is in ratio to the lead of the machine, therefore

$$\frac{\text{Driven gears}}{\text{Driving gears}}=\frac{\text{Required spiral}}{\text{Lead of machine}}.$$

That is, the ratio of the driven gears to the driving gears equals the required spiral divided by the lead of the machine.

Suppose, for instance, it is desired to cut a spiral of 20″ to one turn, on a machine with a lead of 10″. It can be expressed as $\frac{20}{10}$, but as we need 4 gears to obtain a spiral, we will resolve $\frac{20}{10}$ into the factors $\frac{4}{2}\times\frac{5}{5}$, which, multiplied together, give $\frac{20}{10}$.

As we cannot have gears with so few teeth as 4, 2 or 5, we must multiply both terms of the fraction in each case by a number which will give us a gear of practicable size. (Both terms of a fraction can be multiplied by the same number without changing its value.) We did a similar thing in finding the gears for thread cutting, upon the engine lathe. Thus we can multiply $\frac{4}{2}$ by $\frac{20}{20}$, giving us $\frac{80}{40}$, and $\frac{5}{5}$ multiplied by $\frac{10}{10}$ gives us $\frac{50}{50}$; $\left(\frac{80}{40}\times\frac{50}{50}=\frac{400}{200}=\frac{20}{10}\right.$, our original ratio$\left.\right)$. We now have, therefore, $\frac{80}{40}\times\frac{50}{50}$ as our ratio of driven gears to driving gears; that is, the former will be 80 and 50, and the latter 40 and 50. These numbers, of course, mean the number of teeth upon the respective gears. By reference to Fig. 117 we now see that we need,

an 80 gear on the worm shaft,
a 50 gear for the first gear on the stud,
a 50 gear for the second gear on the stud, and
a 40 gear on the screw.

These gears will give a spiral of 20″ to one turn, which can be readily seen, as the size of the gear on the worm is double that of the screw gear, thus doubling the lead of 10″, both stud gears being equal.

80. Obtaining Angle of the Platen. Having determined the gears, it will be necessary now to swivel the lathe or platen a certain number of degrees for cutter clearance.

We will assume that it is the spiral groove in a twist drill of 1″ diameter that we desire. There are two ways of getting the angle of the platen: one by laying it out on a sheet of tin or paper and using a bevel protractor, and the other by figures.

The graphical solution is as follows: We know that the length is to be 20″; draw a horizontal line 20″ long, as in Fig. 119. The diameter is 1″, but we know that the spiral traverses the whole circumference, which is 3.1416 times the diameter. Draw a vertical line of 3.1416″ at the extreme right-hand end of the 20″ horizontal line, and connect the two points *a* and *b* with a line *c*. With a bevel protractor the angle of this line can be obtained,

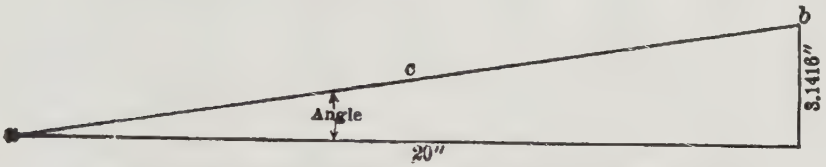


FIG. 119.—Graphical Solution (Scale one-quarter size.)

and by cutting out the paper figure and winding it around the work, the angle is indicated. While this method is easy to understand, it is not so easy to lay off the distance 3.1416″, but it will help the student if he bears in mind that this is approximately $3\frac{1}{7}$″.

The method of figuring the angle is quite simple, using the terms of elementary trigonometry.

Taking the same spiral of 20″, the vertical line of 3.1416″ in the triangle, Fig. 119, divided by the horizontal line of 20″, is the tangent of the angle at *a*.

$$\frac{3.1416}{20} = .15708 = \text{tangent angle at } a.$$

Looking in a table of natural tangents, see pages 122 and 123, we find the number .15708 is not given, the nearest to it being .15838, which corresponds to 9°. As .15708 is

NATURAL TANGENT

Deg.	0′	10′	20′	30′	40′	50′	60′	
0	.00000	.00290	.00581	.00872	.01163	.01454	.01745	89
1	.01745	.02036	.02327	.02618	.02909	.03200	.03492	88
2	.03492	.03783	.04074	.04366	.04657	.04949	.05240	87
3	.05240	.05532	.05824	.06116	.06408	.06700	.06992	86
4	.06992	.07285	.07577	.07870	.08162	.08455	.08748	85
5	.08748	.09042	.09335	.09628	.09922	.10216	.10510	84
6	.10510	.10804	.11099	.11393	.11688	.11983	.12278	83
7	.12278	.12573	.12869	.13165	.13461	.13757	.14054	82
8	.14054	.14350	.14647	.14945	.15242	.15540	.15838	81
9	.15838	.16136	.16435	.16734	.17033	.17332	.17632	80
10	.17632	.17932	.18233	.18533	.18834	.19136	.19438	79
11	.19438	.19740	.20042	.20345	.20648	.20951	.21255	78
12	.21255	.21559	.21864	.22169	.22474	.22780	.23086	77
13	.23086	.23393	.23700	.24007	.24315	.24624	.24932	76
14	.24932	.25242	.25551	.25861	.26172	.26483	.26794	75
15	.26794	.27106	.27419	.27732	.28046	.28360	.28674	74
16	.28674	.28989	.29305	.29621	.29938	.30255	.30573	73
17	.30573	.30891	31210	.31529	.31850	.32170	.32492	72
18	.32492	.32813	.33136	.33459	.33783	.34107	.34432	71
19	.34432	.34758	.35084	.35411	.35739	.36067	.36397	70
20	.36397	.36726	.37057	.37388	.37720	.38053	.38386	69
21	.38386	.38720	.39055	.39391	.39727	.40064	.40402	68
22	.40402	.40741	.41080	.41421	.41762	.42104	42447	67
23	.42447	.42791	.43135	.43481	.43827	.44174	.44522	66
24	.44522	.44871	.45221	.44572	.45924	.46277	.46630	65
25	.46630	.46985	.47341	.47697	.48055	.48413	.48773	64
26	.48773	.49133	.49495	.49858	.50221	.50586	.50952	63
27	.50952	.51319	.51687	.52056	.52427	.52798	.53170	62
28	.53170	.53544	.53919	.54295	.54672	.55051	.55430	61
29	.55430	.55811	.56193	.56577	.56961	.57347	57735	60
30	.57735	.58123	.58513	.58904	.59297	.59690	.60086	59
31	.60086	.60482	.60880	.61280	.61680	.62083	.62486	58
32	.62486	.62892	.63298	.63707	.64116	.64528	.64940	57
33	.64940	.65355	.65771	.66188	.66607	.67028	.67450	56
34	.67450	.67874	.68300	.68728	.69157	.69588	.70020	55
35	.70020	.70455	.70891	.71329	.71769	.72210	.72654	54
36	.72654	.73099	.73546	.73996	.74447	.74900	.75355	53
37	.75355	.75812	.76271	.76732	.77195	.77661	.78128	52
38	.78128	.78598	.79069	.79543	.80019	.80497	.80978	51
39	.80978	.81461	.81946	.82433	.82923	.83415	.83910	50
40	.83910	.84406	.84906	.85408	.85912	.86419	.86928	49
41	.86928	.87440	.87955	.88472	.88992	.89515	.90040	48
42	.90040	.90568	.91099	.91633	.92169	.92709	.93251	47
43	.93251	.93796	.94345	.94896	.95450	.96008	.96568	46
44	.96568	.97132	.97699	.98269	.98843	.94919	1.0000	45
	60′	50′	40′	30′	20′	10′	0′	Deg

NATURAL COTANGENT

NATURAL TANGENT

Deg.	0′	10′	20′	30′	40′	50′	60′	
45	1.0000	1.0058	1.0117	1.0176	1.0235	1.0295	1.0355	44
46	1.0355	1.0415	1.0476	1.0537	1.0599	1.0661	1.0723	43
47	1.0723	1.0786	1.0849	1.0913	1.0977	1.1041	1.1106	42
48	1.1106	1.1171	1.1236	1.1302	1.1369	1.1436	1.1503	41
49	1.1503	1.1571	1.1639	1.1708	1.1777	1.1847	1.1917	40
50	1.1917	1.1988	1.2059	1.2131	1.2203	1.2275	1.2349	39
51	1.2349	1.2422	1.2496	1.2571	1.2647	1.2723	1.2799	38
52	1.2799	1.2876	1.2954	1.3032	1.3111	1.3190	1.3270	37
53	1.3270	1.3351	1.3432	1.3514	1.3596	1.3680	1.3763	36
54	1.3763	1.3848	1.3933	1.4019	1.4106	1.4193	1.4281	35
55	1.4281	1.4370	1.4459	1.4550	1.4641	1.4733	1.4825	34
56	1.4825	1.4919	1.5013	1.5108	1.5204	1.5301	1.5398	33
57	1.5398	1.5497	1.5596	1.5696	1.5798	1.5900	1.6003	32
58	1.6003	1.6107	1.6212	1.6318	1.6425	1.6533	1.6642	31
59	1.6642	1.6753	1.6864	1.6976	1.7090	1.7204	1.7320	30
60	1.7320	1.7437	1.7555	1.7674	1.7795	1.7917	1.8040	29
61	1.8040	1.8164	1.8290	1.8417	1.8546	1.8676	1.8807	28
62	1.8807	1.8940	1.9074	1.9209	1.9347	1.9485	1.9626	27
63	1.9626	1.9768	1.9911	2.0056	2.0203	2.0352	2.0503	26
64	2.0503	2.0655	2.0809	2.0965	2.1123	2.1283	2.1445	25
65	2.1445	2.1609	2.1774	2.1943	2.2113	2.2285	2.2460	24
66	2.2460	2.2637	2.2816	2.2998	2.3182	2.3369	2.3558	23
67	2.3558	2.3750	2.3944	2.4142	2.4342	2.4545	2.4750	22
68	2.4750	2.4959	2.5171	2.5386	2.5604	2.5826	2.6050	21
69	2.6050	2.6279	2.6510	2.6746	2.6985	2.7228	2.7474	20
70	2.7474	2.7725	2.7980	2.8239	2.8502	2.8770	2.9042	19
71	2.9042	2.9318	2.9600	2.9886	3.0178	3.0474	3.0776	18
72	3.0776	3.1084	3.1397	3.1715	3.2040	3.2371	3.2708	17
73	3.2708	3.3052	3.3402	3.3759	3.4123	3.4495	3.4874	16
74	3.4874	3.5260	3.5655	3.6058	3.6470	3.6890	3.7320	15
75	3.7320	3.7759	3.8208	3.8667	3.9136	3.9616	4.0107	14
76	4.0107	4.0610	4.1125	4.1653	4.2193	4.2747	4.3314	13
77	4.3314	4.3896	4.4494	4.5107	4.5736	4.6382	4.7046	12
78	4.7046	4.7728	4.8430	4.9151	4.9894	5.0658	5.1445	11
79	5.1445	5.2256	5.3092	5.3955	5.4845	5.5763	5.6712	10
80	5.6712	5.7693	5.8708	5.9757	6.0844	6.1970	6.3137	9
81	6.3137	6.4348	6.5605	6.6911	6.8269	6.9682	7.1153	8
82	7.1153	7.2687	7.4287	7.5957	7.7703	7.9530	8.1443	7
83	8.1443	8.3449	8.5555	8.7768	9.0098	9.2553	9.5143	6
84	9.5143	9.7881	10.078	10.385	10.711	11.059	11.430	5
85	11.430	11.826	12.250	12.706	13.196	13.726	14.300	4
86	14.300	14.924	15.604	16.349	17.169	18.075	19.081	3
87	19.081	20.205	21.470	22.904	24.541	26.431	28.636	2
88	28.636	31.241	34.367	38.188	42.964	49.103	57.290	1
89	57.290	68.750	85.939	114.58	171.88	343.77	∞	0
	60′	50′	40′	30′	20′	10′	0′	Deg.

NATURAL COTANGENT

slightly less than .15838, the angle to which we must turn the platen is a little less than 9°.

81. Milling Cutters. The simplest form of milling cutter is commonly termed a fly cutter. Such a cutter, with a single cutting edge formed to suit any desired shape, is cheaper than a regularly formed milling cutter, and is useful in model work, particularly when only one or two parts of a kind are required, and when expense is a factor.

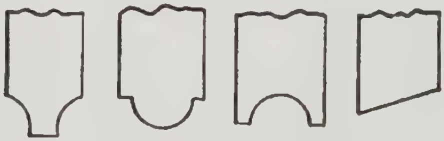
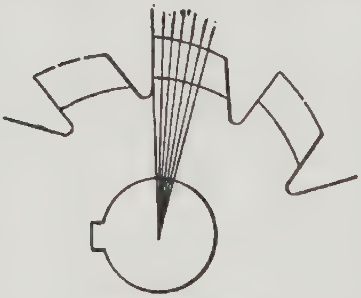


FIG. 120.—Forms of Fly Cutter.



Formed Cutter

FIG. 121.—Lines Indicating Repeated Grinding without Affecting Size and Shape of Cut.

It is particularly adapted to the production of irregular shapes and contours, such as are required on screw machines. Having only a single cutting edge, the wear is of course greater than on a multiple tooth cutter, hence it needs grinding more frequently.

All cutters are form cutters in that they produce some form, but the term **formed cutter** is applied to the construction of the cutter from the standpoint of clearance, which is so designed that the size of the cut and the form remain constant, no matter how often it is ground, as indicated in Fig. 121.

There is a limit to the size of these solid formed cutters, and the limit is controlled partly by the economic factor. First, the amount of tool steel, which is expensive, is considerable in a large cutter. Second, when a tooth edge breaks it practically invalidates the whole cutter. The limit for such cutters is about 7″; after this size is exceeded, the inserted-tooth milling cutter takes its place. This is a built-up cutter where only small pieces of tool steel are required for the cutting teeth; the body of the cutter may be made from cheaper material, such as cast iron or soft

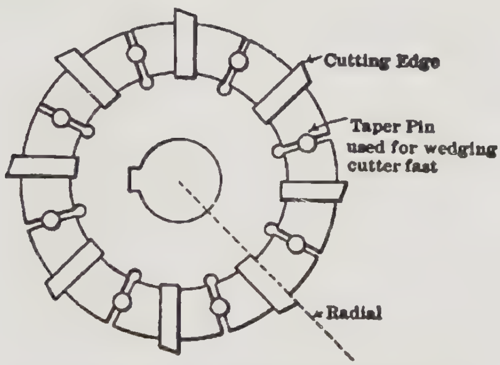


Fig. 122.—Inserted Tooth Cutter.

machinery steel. In case of breakage of the tooth edges, the expense of renewing is reduced to a minimum. See Fig. 122.

82. Different Cutters for Different Uses. There are many different milling cutters regularly made and used besides numerous special cutters for less common use. The following list contains the more usual ones; the names, sizes, and specifications conform to Brown and Sharpe practice. They are made in both carbon and high speed steels.

Plain Mills, with teeth upon the face or edge only, for surfacing; widths range from $\frac{3}{16}$″ to 6″ and diameters from $2\frac{1}{4}$″ to $4\frac{1}{2}$″. Where the face is more than $\frac{3}{4}$″ wide,

set of cutters for each pitch will cut all the gears from a rack down to a pinion of 12 teeth.

Worm Hobs for cutting the teeth of worm-wheels.

Formed Cutters for special work; these may be obtained in a great variety of outlines. They are made to special order only.

There are other cutters which, in most cases, are modifications of those named.

Various shapes are used for fluting taps, according to the preference of the manufacturer. Figs. 123 and 124 show two common froms of these, *m* and *n*. In using the cutter *m*, the distance marked *x* is $\frac{2}{10}$ of the diameter

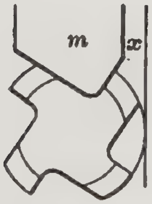


FIG. 123.

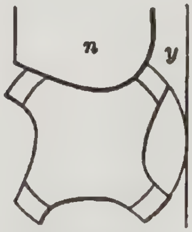


FIG. 124.

Cutters for Fluting Tops.

of the work, and the depth of the cut for this cutter is .23 of the same diameter. In using *n*, the distance *y* andthe depth of the cut are approximately $\frac{1}{8}$ of the diameter of the work. Most shops have tables of cutters posted, from which these measurements may be taken.

The width of cutters for milling the spiral grooves in twist drills varies among the different manufacturers, but in each case the increase in the width of the cutter is in direct proportion to the increase in the diameter of the drill to be cut, as indicated on the chart, Fig. 125. From this chart it may be seen that the approximate width of the cutter to be used in milling twist drills is 60 per cent, or $\frac{3}{5}$, of the diameter of the drill to be cut, For example, a drill 1″ in diameter would require a cutter .6″ wide. The

center line of the cutter is placed directly over the center of the drill *before* the platen is swiveled to the correct angle. One method of arriving at this center line of the work is to bring the cutter to within a few thousandths of an inch of the work, using stiff paper, such as a piece

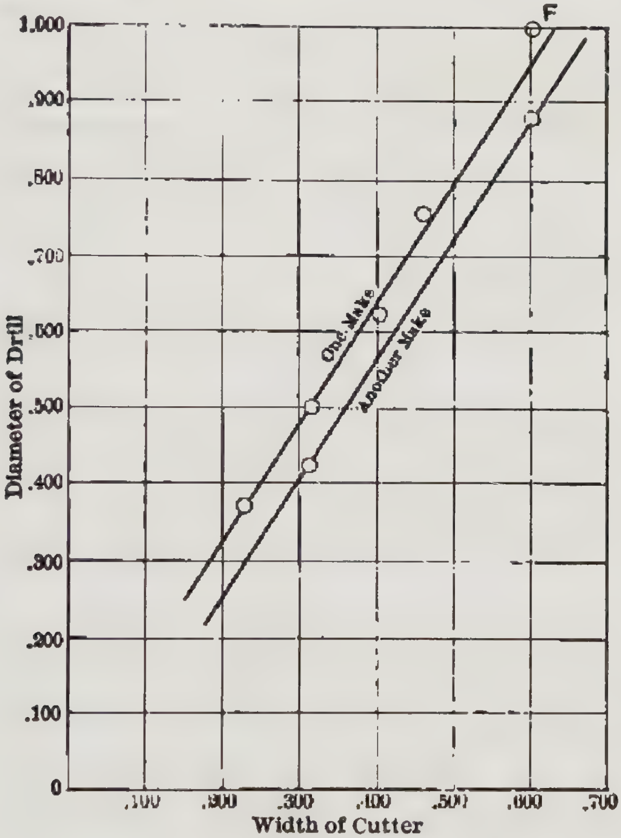


Fig. 125.—Increase in Width of Cutter with Diameter of the Drill.

of an envelope or writing paper about .004″ to .005″ thick to feel the contact and then passing the cutter over the work until contact through the paper is obtained; then use the vertical screw micrometer, advancing .001″ at a time, each time passing the cutter over the work. Finally, a hair line will appear on the exact center of the work, to which the center line of the cutter must be brought.

The depth of the cut is approximately $\frac{3}{16}$ of the radius of the drill; there is considerable variance among manufacturers. Moreover, the use for which the drill is intended is an important factor in considering this depth, upon which the thickness of the point depends. According to all practice this thickness increases as the drill becomes shortened through grinding and breakage.

When a very wide cut is required, or several different planes and shapes are to be produced at once, several cutters are used and the term *gang milling* applied, as illustrated in Fig. 113. On broad surfaces a milling cutter

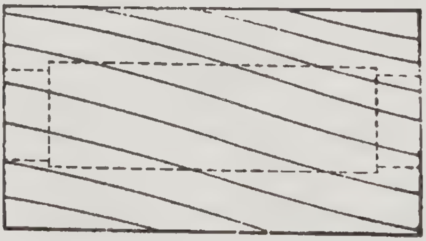


Fig. 126.—Spiral Mill, Showing Internal Construction.

is used having the teeth cut on a spiral, which gives a *shearing* cut, requiring the minimum energy, for the reason that the cutting edges are at an angle. The cutting action is similar to that of a file.

Note that this cutter is recessed, leaving only end bearings to fit the arbor. This recessing is for the purpose of counteracting what occurs during the hardening and tempering process. When the cutter is plunged into the hardening solution, only the outside comes in contact with the chill of the solution, the inside being still hot. The chill effects a contraction on the outside while the inside is still expanded, resulting in a distortion of the cutter, as shown in Fig. 127. This would require lapping or grinding out, consuming unnecessary time and requiring exceedingly high-grade skill, for it is essential that the cutter

should fit the arbor perfectly without any tendency to rock. By recessing, only the end bearings need be finished, requiring the minimum bearing on the arbor. See Fig. 128. This is an example of the economic considerations with which every mechanic should be familiar.

Fig. 127.

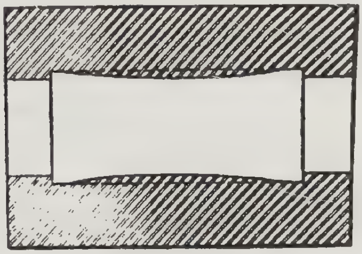


Fig. 128.

The angular cutter which is used to cut a spiral cutter is made usually with faces of 12° and 48° inclination to the plane of the cutter, thus forming a 60° angle of the profile of the cutter. The cutter is set $\frac{1}{10}$ of the diameter

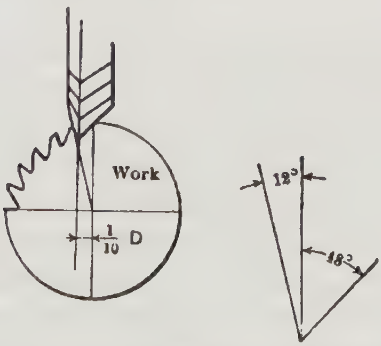


Fig. 129.—Cutters for Twist Drills.

of the work off center, bringing the 12° face in line with the radius of the work, which is the desirable angle for the cutting faces of the spiral teeth. See Fig. 129. The center line of the cut must be obtained *before* swinging the platen to the desired angle.

In fluting end mills a 70° cutter is usually employed but an 80° gives a stronger tooth.

83. Width of Cut. In using any milling cutters, especially saws and slot cutters, or where the width of the cut is important, it is necessary to be very careful. Do not place too much reliance upon a measurement of the cutter, even with the micrometer, because there is always danger that the cutter will not run perfectly true sidewise; in that event the slot will be wider than the cutter. You can test the width of the cut by making a trial cut in a piece of cast iron, or other material, and then filing a piece of

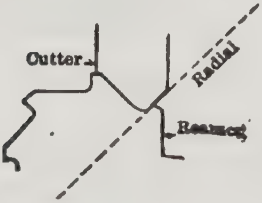


FIG. 130.

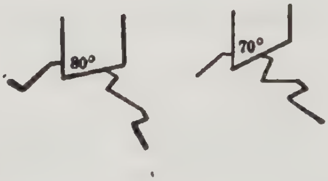


FIG. 131.

Varius Shapes of Cutters for Special Purposes.

brass to fit it; a micrometer measurement of this will show what the cutter will actually do.

To test the accuracy of the setting of a cutter for cutting a key-way on the center of a shaft, a trial slot may be made on a waste piece; then turn this piece end for end on the centers, and try the cutter in the slot.

A general rule, suggested by the foregoing, is this: *Never take anything for granted, always prove your work.*

84. Cutting Gears. In cutting spur gears upon the milling machine the blank may be held upon an ordinary arbor with a dog attached, although a taper shank arbor fitting the index spindle and supported by the tail stock center is a better method. If the dog is used care is necessary to see that it does not spring the arbor.

The two important points to be observed in setting the

machine are: first, that the cutter is central with the line of index centers, and second, that the cut will be the correct depth. To test the first, use the method given in connection with the cutting of a central key-way in a shaft. For the second, the depth may be marked on the side of the blank, but a better way is to raise the blank carefully until the cutter just grazes it; then set the micrometer disc on the vertical feed shaft at zero, move the blank away from the cutter horizontally, and raise it the number of thousandths required for the correct depth of the teeth.

According to Brown and Sharpe, it is more economical to mill the faces of worm wheels than to turn them in the engine lathe, and the results are better. In cutting the teeth of a worm wheel a disc cutter may be used to rough them out; the cutter is set central with the line of the index centers and the center of the face of the wheel is brought under the center of the cutter arbor. The platen is then clamped and the saddle turned for the correct angle of the teeth. The teeth are finished by using a worm hob; when the shaft of the worm wheel is at 90° to the worm shaft the saddle should be set at zero.

Bevel gears can be cut on a universal milling machine although the results only approximate the theoretically correct teeth. The tooth of a bevel gear tapers from end to end; therefore the outline at the large end is not the same as at the small end. A rotary gear cutter must, of course, cut the same outline throughout the length of the tooth. The usual method is to take two cuts for each space, one for each side, the blank being so held that the tooth will taper in thickness. To modify the outline to a practicable shape, the tooth is then filed. The filing is, in effect, to round over the top of the tooth down to the pitch line, and is heaviest at the small end, tapering off to nothing at the large end. A workman can become very skilful at this filing.

85. General Rules. *A milling cutter should always*

run away from the cut, in the direction indicated in Fig. 132. If run in the opposite direction, or toward the cut, it would tend to climb up on the uncut metal and this would result in broken teeth.

The efficiency of the milling cutter depends upon the sharpness of the cutting edge. No multiple tooth cutter can be ground by hand.

The greatest care should be taken in the grinding or resharpening of the cutter also, for if the teeth are not ground uniformly the cutter will run out of true.

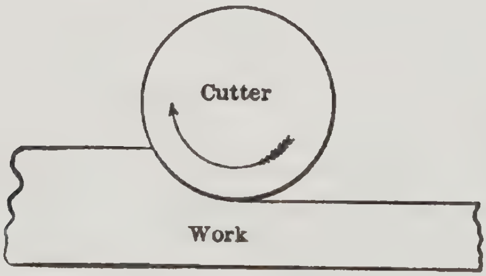


Fig. 132.—Direction of Rotation of a Milling Cutter.

In milling wrought iron and steel a lubricant is necessary; lard oil is best for this purpose.

86. Number of Teeth on Cutters. Practice varies in this respect, the English practice running to finer teeth than the American. There are two sides to the question; with finer teeth the number is larger, but in addition to this there must be considered the resistance offered by the increased number of cutting points, which limits the depth of the cut and the feed. The coarser, longer teeth give possibilities of greater depth of cut, because of more clearance space.

In English practice the circumference of the blank for the milling cutter is divided by .28; in American practice by .40; as, for example, in making a cutter of 3″ diameter:

$$3 \times 3.141 = 9.423$$

$$9.423 \div .28 = 33.6 \text{ (34 teeth)}$$

$$9.423 \div .40 = 23.5 \text{ (24 teeth)}$$

87. Speeds and Feeds of Milling Cutters. So many varying conditions must be considered that it is impossible to give figures for speeds and feeds that could be of much value to the mechanic. The time element is a factor that is too often ignored, and while there are many tables of speeds and feeds now extant, experience has proven that little value can be attached to them. There are many grades of cast iron and many of steel. In one case it might be perfectly feasible to run 80′ per minute, with a 10″ or 12″ feed for a depth of .040″ on a length of cut of 1½″. Increase the depth of the cut to .080″ and the length of the cut to 6″, where the cutter remains in contact a longer period of time, and it will be found economical to reduce the speed to 60′ per minute, and the feed to 2″ per minute.

Milling cutters are expensive, and when the keen cutting edge of the tooth is once gone it will not cut, but will simply peen the metal and rack the machine. So it is always economical to keep the feeds and speeds well within safe limits, because the time required to do the work is not the only item upon which cheap production is based. The life of the cutter and the depreciation of the machine tool, to say nothing of the overhead charges, must all be considered. Experience with many kinds of materials and tool steels prove that the following figures are much nearer the economic limit than many of the usual tables give:

Annealed tool steel...	28 feet/m, feed .6″/m.
Soft steel...........	42 feet/m, feed .8″/m.
Cast iron...........	50 to 60 feet/m, feed 1¼″/m.
Brass...............	90 to 100 feet/m, feed 2″/m, according to its alloy
Bronze.............	78 feet/m, feed 1½″/m.

CHAPTER XIII

MEASURING INSTRUMENTS

Micrometer and vernier. Conversion tables. Measuring blocks; how constructed and used. Tables of decimal equivalents.

THE simplest measuring instrument used by the machinist is the steel scale with its various graduations. In connection with it, for use where only approximately accurate measurements are required, are the familiar calipers, inside and outside, of several designs.

88. The Micrometer. The micrometer caliper is designed for very accurate measurements, and should be in the hands of every mechanic and every beginner. The day of the two-foot rule is past. We now talk in thousandths of inches instead of sixteenths, and it is well to learn also to think in thousandths, because such thinking helps to form habits of precision and care which the would-be successful man needs.

Fig. 133 shows the common type of micrometer, but micrometer measurements can be made in very many ways other than with this particular type. Any two numbers which, multiplied together, give a product of 1000 are the basis of the micrometer system. For example, Fig. 134 is a screw of 10 threads per inch with a disc *a* fastened to it; this disc, graduated in 100 parts, will give micrometer measurements; that is, the point of the screw will advance .001″ when the disc is rotated one graduation mark.

The type of tool represented by Fig. 133 has 40 threads per inch on the spindle and is graduated on the barrel or sleeve *a* into 25 divisions; $40 \times 25 = 1000$. One turn of

the barrel *a* advances the spindle which is attached to it .025″ on the extension *b*, over which the barrel slides. You will note the small divisions represented in Fig. 135, each one of which represents one turn of the barrel, or .025″; four turns of the barrel, or .100″, is represented by the long line at 1; 8 turns or .200″ by the long line at 2, and so on up to the inch, or 1.000″.

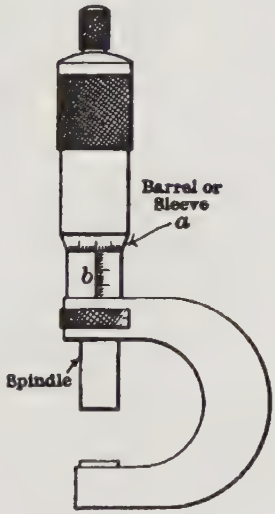


FIG. 133.

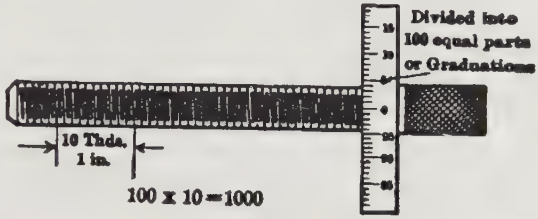


FIG. 134.

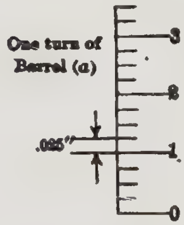


FIG. 135.

The Micromoter.

89. Reading the Micrometer. In Fig. 136 is represented a micrometer to which the beginner can readily apply the text and learn the reading. The rotation of the barrel is toward you to increase the reading; away from you to decrease it. The barrel is marked 0, 5, 10, 15, 20, as in the lower cut. As each of the small spaces between 0–1, in the upper cut, represents one turn of the barrel, or .025″, and as there are 14 of these spaces uncovered, therefore, $14 \times .025'' = .350''$, the correct reading.

Fig. 137 requires a fractional reading. There are in

this cut five of these small (.025″) spaces and a fraction of another uncovered. The five spaces give us: $5 \times .025 =$ .125″. To determine the fractional part of the sixth space, which is uncovered we must note the position of the barrel. When the end of the barrel was on the line between the fifth and sixth spaces, the 0 mark on the barrel coincided with the longitudinal line on the stem g; to uncover this part

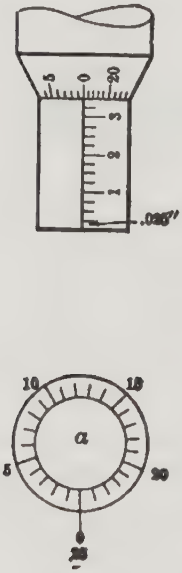


FIG. 136.

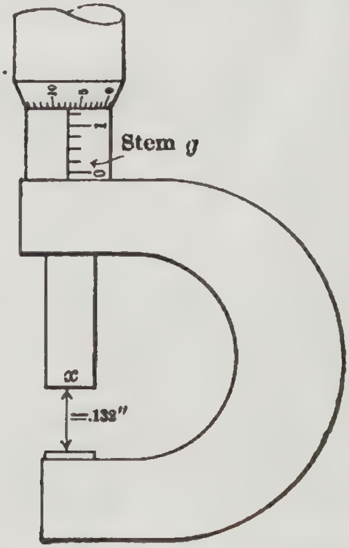


FIG. 137.

Micromoter, Showing Method of Reading.

of the sixth space the barrel has been turned through 7 (5+2) of its own divisions. As each of these divisions represents .001″ ($\frac{1}{25}$ of $\frac{1}{40}$), this partial space represents .007″. Therefore we have, .125″+.007″=.132″ for the complete reading.

Now, if the barrel were further rotated, more of the sixth space would be uncovered, and the reading on the barrel would increase until the 0 line would again coincide with the line on the stem g, when six of the stem divisions would be uncovered; 6 times .025, or .150″ would be the reading.

scale *a* by means of the small screw *c*, and gives readings of $\frac{1}{40}$th of an inch on the limb and $\frac{1}{25}$th of this amount on the vernier *b*. As in the micrometer, $\frac{1}{25}$ of $\frac{1}{40}=.001$. These graduations might just as well be 50 per inch on the limb and 20 on the vernier, these 20 equalling 19 of the limb divisions ($\frac{1}{20}$ of $\frac{1}{50}=.001$).

91. Reading a Vernier. First, read the last limb subdivision passed over by the zero of the vernier as the reading of the limb. Second, look along the vernier scale until a line is found upon it which coincides exactly with a line on the limb scale. Read the number of the line

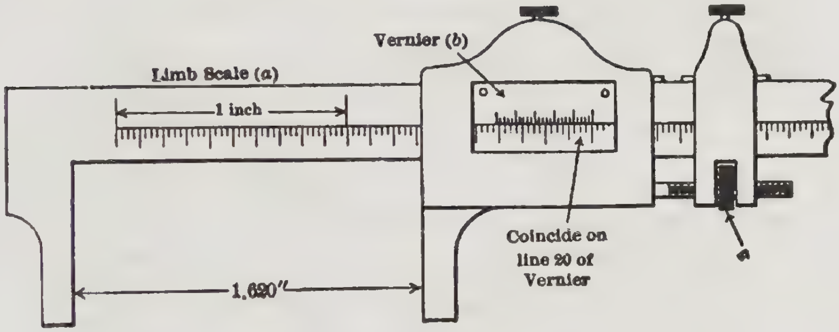


FIG. 138.—The Vernier Caliper.

from the scale of the vernier; this is added to the reading of the limb scale to obtain the total reading.

In Fig. 138, if you read along the limb scale, you will note that the zero on the vernier is beyond the 16th long line on the limb scale; the reading is $1''+\frac{6}{10}$ $(1.6'')+$a fractional part of another 10th of an inch. Now it is necessary to get the vernier reading to add to this, as you will note that the zero mark of the vernier is between two lines on the limb. Read along the vernier scale and you find that line number 20 on the vernier coincides with a line on the limb scale. Therefore .020″ is the vernier reading and we have $1.6''+.020''=1.620''$ as the total reading of the opening between the jaws of the caliper. A little practice will enable you to read very accurately and very quickly.

A vernier scale is often placed upon the stem of a micrometer caliper, and allows readings to the 10,000th part of an inch.

92. Micrometer Stops. The use of the micrometer system of measurements is pretty old, but to-day modern machine builders, as already noted, use it on the feed mechanisms, and it even finds use as a stop on the lathe beds, consisting, in such cases, of a screw and disc similar to that in Fig. 139, and applied as in Fig. 140.

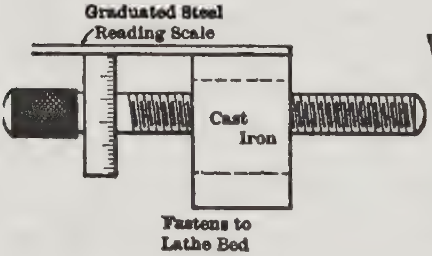


FIG. 139.

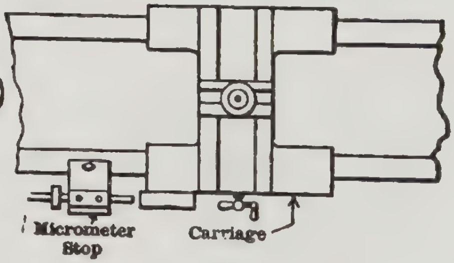


FIG. 140.

Micromoter Stop for Lathe Bed.

93. Caliper Squares. The caliper square resembles the vernier caliper without the vernier graduation. It is not suitable where extreme accuracy is required, but is used where duplication is necessary, and when the number of pieces of work will not warrant the expense of a set of fixed gauges.

94. Measuring Blocks. It is often desirable to have a piece of work very accurate as regards *parallelism* of slots or grooves, even when it is not essential that these slots be of an exact stipulated size. For example, a small cross-head is required to slide between guides whose parallelism must be absolutely accurate, yet the width between the guides need not measure to within a few thousandths of a stated dimension.

Small pieces of steel of various sizes and shapes to

suit the required conditions are machined, hardened and lapped, and used as gauges. They are sometimes square, sometimes round, and at other times angular to fit dovetails, etc.

95. The Metric System. In many of our American shops to-day the metric system of measurement is largely used; the micrometer and vernier calipers are graduated to suit either the English or metric system. It will be well, therefore, for the mechanic to familiarize himself with both systems.

TABLE OF METRIC LINEAR MEASUREMENTS

10 Millimeters = 1 Centimeter.	1 Centimeter = .3937 Ins.
10 Centimeters = 1 Decimeter.	1 Decimeter = 3.937 "
10 Decimeters = 1 Meter.	1 Meter = 39.37 "

CONVERSION OF ENGLISH TO METRIC MEASURE

English	French or metric
39.37 inches	1 meter
1 foot	.3048 meter
.3937 inch	1 centimeter
1 inch	2.154 centimeters
.03937 inch	1 millimeter

$\frac{1}{25}$ inch (approximately) is equal to a millimeter.

TABLE OF DECIMAL INCH EQUIVALENTS OF MILLIMETERS

$\frac{1}{10}$ mm. = .00394″	8 mm. = .31496″	18 mm. = .70866′,
$\frac{1}{5}$ " = .00787″	9 " = .35433″	19 " = .74803″
$\frac{1}{2}$ " = .01969″	10 " = .39370″	20 " = .78740″
1 " = .03937″	11 " = .43307″	21 " = .82677″
2 " = .07874″	12 " = .47244″	22 " = .86614″
3 " = .11811″	13 " = .51181″	23 " = .90551″
4 " = .15748″	14 " = .55118″	24 " = .94488″
5 " = .19685″	15 " = .59055″	25 " = .98425″
6 " = .23622″	16 " = .62992″	26 " = 1.02362″
7 " = .27559″	17 " = .66929″	

TABLE OF DECIMAL EQUIVALENTS OF EIGHTHS, SIXTEENTHS, THIRTY-SECONDS AND SIXTY-FOURTHS OF AN INCH

Eighths	Sixteenths	Thirty-seconds	
$\frac{1}{8}$ = .125	$\frac{1}{16}$ = .0625	$\frac{1}{32}$ = .03125	$\frac{17}{32}$ = .53125
$\frac{1}{4}$ = .250	$\frac{3}{16}$ = .1875	$\frac{3}{32}$ = .09375	$\frac{19}{32}$ = .59375
$\frac{3}{8}$ = .375	$\frac{5}{16}$ = .3125	$\frac{5}{32}$ = .15625	$\frac{21}{32}$ = .65625
$\frac{1}{2}$ = .500	$\frac{7}{16}$ = .4375	$\frac{7}{32}$ = .21875	$\frac{23}{32}$ = .71875
$\frac{5}{8}$ = .625	$\frac{9}{16}$ = .5625	$\frac{9}{32}$ = .28125	$\frac{25}{32}$ = .78125
$\frac{3}{4}$ = .750	$\frac{11}{16}$ = .6875	$\frac{11}{32}$ = .34375	$\frac{27}{32}$ = .84375
$\frac{7}{8}$ = .875	$\frac{13}{16}$ = .8125	$\frac{13}{32}$ = .40625	$\frac{29}{32}$ = .90625
	$\frac{15}{16}$ = .9375	$\frac{15}{32}$ = .46875	$\frac{31}{32}$ = .96875

Sixty-fourths

$\frac{1}{64}$ = .015625	$\frac{17}{64}$ = .265625	$\frac{33}{64}$ = .515625	$\frac{49}{64}$ = .765625
$\frac{3}{64}$ = .046875	$\frac{19}{64}$ = .296875	$\frac{35}{64}$ = .546875	$\frac{51}{64}$ = .796875
$\frac{5}{64}$ = .078125	$\frac{21}{64}$ = .328125	$\frac{37}{64}$ = .578125	$\frac{53}{64}$ = .828125
$\frac{7}{64}$ = .109375	$\frac{23}{64}$ = .359375	$\frac{39}{64}$ = .609375	$\frac{55}{64}$ = .859375
$\frac{9}{64}$ = .140625	$\frac{25}{64}$ = .390625	$\frac{41}{64}$ = .640625	$\frac{57}{64}$ = .890625
$\frac{11}{64}$ = .171875	$\frac{27}{64}$ = .421875	$\frac{43}{64}$ = .671875	$\frac{59}{64}$ = .921875
$\frac{13}{64}$ = .203125	$\frac{29}{64}$ = .453125	$\frac{45}{64}$ = .703125	$\frac{61}{64}$ = .953125
$\frac{15}{64}$ = .234375	$\frac{31}{64}$ = .484375	$\frac{47}{64}$ = .734375	$\frac{63}{64}$ = .984375

CHAPTER XIV

GEARING

Different kinds of gearing and their application to machine design. Their various uses. Calculations for different gears. Diametral pitch, circular pitch, linear pitch. Worm wheel and worm rack tooth and its development. Spiral gears.

96. Underlying Principles. There are many treatises on gearing, covering many hundreds of pages, for the subject is scarcely exhausted in a single book, but there are a few simple principles which underlie and form the basis of these treatises, with which the machinist must be familiar.

The term gearing is applied to positive driving mechanism, when, through a train of gears, machinery is put in motion, either to drive the work or the tool. By a **train** of gearing we mean the sequence of gears which make up the complete transmission series.

Power is applied to the lathe, for example, through its back gears, and the four wheels or gears constituting the train include the small gear on the end of the cone pulley, the large gear on the back gear shaft, the smaller gear on the same shaft, and the large gear on the main spindle of the lathe. The transmission is direct between the first and second, through the back gear shaft between the second and third, and direct between the third and fourth.

97. Kinds of Gears. The **spur** gear is the usual plain gear; it is most commonly used for the transmission of power in machine tools.

The **bevel gear** is used to transmit motion between two shafts at any angle to each other. Bevel gears may be and

deeper than the length of the half-tooth, because *clearance* is necessary between the tops of the teeth upon one gear and the bottoms of the spaces between the teeth of the other. In Fig. 141, therefore, you will be able to find the pitch circles (our friction wheels), the circles locating the tops of the teeth (*addendum circles*), the circles locating the depth to which the teeth of the other gear extend (*working depth circles*), and the circles locating the actual bottoms of the teeth (*whole depth circles*).

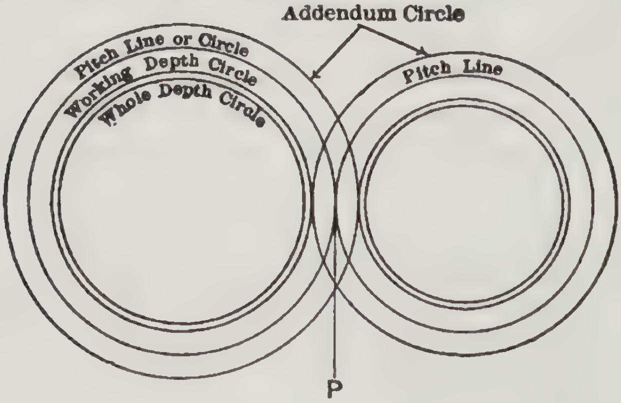


Fig. 141.

99. Pitch. There are certain other terms used in reference to gears, which the student is now prepared to learn. We speak of *pitch* as *diametral*, and *circular* or *linear*. By **diametral pitch** is meant the number of teeth for every inch of diameter. By **circular**, or **linear pitch** is meant the distance between the centers of two successive teeth, measured on the pitch circle, or pitch line. The thickness of the tooth, on the pitch circle, equals the width of the space between two teeth; each is therefore one-half the circular pitch.

100. Calculating Gears. In calculating a gear the diameter is first obtained; for example, we desire to make a gear wheel with 31 teeth, 5 pitch. The 5 pitch is diametral, and means the number of teeth for every inch

of diameter, hence $31 \div 5 = 6\frac{1}{5}''$ or $6.2''$, the diameter of the gear *on the pitch circle.* Now, to obtain the whole, or outside diameter, we must remember that it is necessary to add to the diameter of the pitch circle the amount the tooth projects beyond it *on each side* of the gear. This projection equals twice the addendum of a tooth. To find the length of the addendum, divide the diameter of the pitch circle by the number of teeth on the gear; $6.2 \div 31 = .2''$. This is called a *module;* as we obtained it by dividing the diameter by the number of teeth $\left(\frac{6.2}{31}\right)$ there is one module for each tooth. But this is the ratio of the whole diameter to the whole number of teeth, and is equal to $\frac{1}{5}$, which is the ratio of one inch of the diameter to the pitch. We may therefore use the fraction which expresses this ratio of diameter to pitch, in calculating the teeth of any gear.

To proceed with our example, we add twice the addendum (or module) to the diameter of the pitch circle. $6\frac{1}{5}'' + \frac{2}{5}'' = 6\frac{3}{5}''$ or $6.6''$, the diameter of the gear across the tops of the teeth, or the diameter of the blank from which the gear is cut.

We now have to determine the depth of the cuts by which the teeth are formed. As we know that the addendum and dedendum are equal, they give us, when added, twice the addendum; therefore this equals the working depth of the tooth. To obtain the whole depth we must add the clearance. It is considered good practice to make this equal to $\frac{1}{16}$ of the working depth. Our calculation is as follows: $\frac{1}{5} \times 2 = \frac{2}{5}''$ working depth. $\frac{1}{16}$ of $\frac{2}{5} = \frac{1}{40}''$ or $.025''$ clearance. $\frac{2}{5}''$ or $.4'' + .025'' = .425''$. We now have the diameter of the blank ($6.6''$) and the depth of the cut ($.425''$).

To summarize our example, we have:

To make a gear of 31 teeth, of 5 diametral pitch, which is the data the machinist would receive:

(1) $31 \div 5 = 6\frac{1}{5}''$ or $6.2''$, the pitch diameter.

(2) $6\frac{1}{5}'' + \frac{2}{5}''$ (two addenda) $= 6\frac{3}{5}''$ or $6.6''$, the diameter of the blank.

(3) $\frac{1}{5} \times 2 = \frac{2}{5}''$ or $.4''$, the working depth of a tooth.

(4) $.4 \times \frac{1}{16} = \frac{.4}{16} = .025''$, the clearance.

(5) $.4 + .025'' = .425''$, the depth of the cut.

Rule for Diameter of Blank. *Divide the number of teeth by the diametral pitch and add twice the pitch ratio.*

An easy form of this rule to remember is this: Add 2 to the number of teeth and divide by the diametral pitch. To prove:

$$\frac{31}{5}+\frac{2}{5} \text{ (first rule)} = \frac{31+2}{5} \text{ (second rule)} = \frac{33}{5} = 6\tfrac{3}{5} \text{ or } 6.6''.$$

If the pitch were 7 instead of 5, we would have:

$$\frac{31}{7}+\frac{2}{7}=\frac{33}{7}=4\tfrac{5}{7}'' \quad \text{or} \quad 4.714''.$$

If the pitch were 8, we would have,

$$\frac{31}{8}+\frac{2}{8}=\frac{33}{8}=4\tfrac{1}{8}'' \quad \text{or} \quad 4.125''.$$

The working depth and clearance would be found in the same way as in the first example.

The rule for determining the distance between the centers of two gears is as follows:

Add the number of teeth in both gears and divide half the sum by the diametral pitch. If a equals the distance and b equals the sum of the teeth, then $a = \frac{b}{2P}$.

101. Circular Pitch. Circular pitch, P, is the distance between the centers of two teeth measured on the pitch line, Fig. 142. The process of calculation is the same as for diametral pitch, only in one case we figure from the diameter and in the other from the circumference.

The axes of a worm wheel and worm are usually at right angles to each other.

The rules for circular pitch apply to the calculation for worm wheels, only the terms are sometimes misunderstood, because a worm may be single, double, triple, or quadruple thread, as the case may be; the term *pitch* may be misapplied, therefore. What it is really essential to know is the advance or *lead* of the worm thread. A single thread worm, for instance, with 3 turns to 1″ has $\frac{1}{3}$ lead.

In a single thread worm *only* are the lead and pitch the same. The pitch is always the distance between the centers of two teeth on the pitch line.

As the worm and worm wheel mesh, the number of threads per inch of length on the worm equals the number of teeth per inch of circumference on the worm wheel. Assuming the worm to have 5 threads per inch, the wheel will have 5 teeth per inch. The circular pitch of the wheel will therefore be $\frac{1}{5}$″. To find the diametral pitch, divide the circumference of a one-inch circle, or 3.1416, by the circular pitch: $3.1416 \div \frac{1}{5} = 3.1416 \times 5$. Therefore we have:

Rule for the Diametral Pitch of a Worm Wheel. Multiply the number of threads per inch on the worm by 3.1416.

Having the number of teeth in the wheel and the diametral pitch, proceed with the calculation as in the case of a spur gear.

These wheels are usually finished with a **hob,** a cutting tool which looks like a worm or screw, grooved to form teeth for cutting.

The diameter of a hob, for milling or hobbing a worm wheel, should be a little larger than the worm,—usually the diameter of the worm plus double the clearance of the tooth. In making this we get the method of calculating the rack tooth tool, because the same tool would be necessary in cutting the worm or the hob.

104. The Rack Tooth. Brown and Sharpe give the following method and calculation for obtaining the rack tooth:

The sides of the rack tooth, in the Brown and Sharpe gear, slope $14\frac{1}{2}°$; to obtain this quickly, draw any semicircle, divide the diameter into four equal parts, set the dividers equal to one of these parts, and project it on the circum-

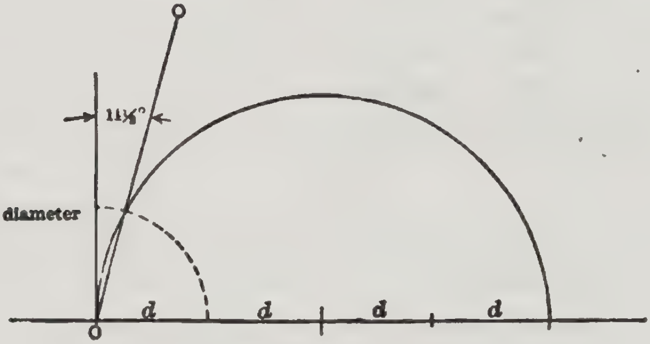


Fig. 143.

ference of the semicircle. Draw the line *OO*, Fig. 143, through these points; this makes an angle of $14\frac{1}{2}°$ with the perpendicular, and gives the side of the rack tooth. Then, to lay out for a tool to make the rack, we would draw a circle of any diameter, and lay off $\frac{1}{4}$ of the diameter on both sides of the center line, and draw lines as in Fig. 144. These show the angle of the tool point.

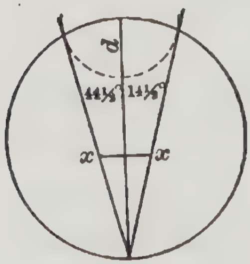


Fig 144.

To obtain the correct width of the point of the tool we must find the width of the bottom of the space between two teeth. We must also find the width of the top of the tooth if we are to attempt to cut the rack. As the dimensions of the teeth of other pitches are proportional to those of 1″ pitch, the atter may be used as constants. We have already found the addendum for this pitch (.3183″), the dedendum (.3683″), and the whole depth (.6866″). To find the widths of the top of the tooth and the bottom of the

space, the following is given: We know the thickness of the tooth on the pitch line is one-half the linear pitch, or $\frac{P'}{2}$. Therefore, letting A = the width of the top, we have:

$$(1)\quad A=\frac{P'}{2}-2(.3183 \tan 14\tfrac{1}{2}^\circ)$$

But $P'=1$; therefore,

$$(2)\quad A=\tfrac{1}{2}-2\,(.3183 \tan 14\tfrac{1}{2}^\circ)$$
$$(3)\quad A=.3354.$$

We also know the space between two teeth on the pitch line is one-half the linear pitch or $\frac{P'}{2}$. Therefore, letting B equal the width of the bottom of the space, we have:

$$(1)\quad B=\frac{P'}{2}-2(.3683 \tan 14\tfrac{1}{2}^\circ);$$

But $P'=1$; therefore,

$$(2)\quad B=\tfrac{1}{2}-2(.3683 \tan 14\tfrac{1}{2}^\circ);$$
$$(3)\quad B=.05-2(.3683\times.25861);$$
$$(4)\quad B=.3095 \text{ or } .31.$$

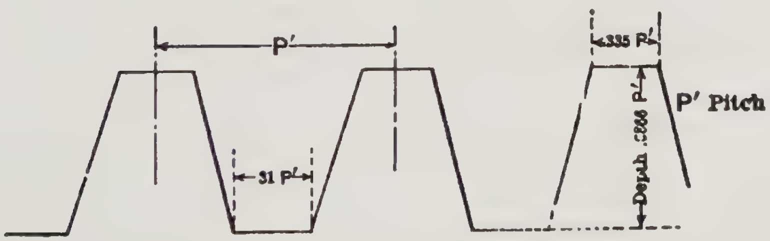


FIG. 145

To use these constants, suppose the linear pitch of our rack is 1.25, we have:

$B=.31\times1.25=.3875''$, width of the point of the tool.

$A=.3354\times1.25=.4192''$, width of the top of the tooth.

Depth of cut $=.6866\times1.25=.8582''$.

In practice, gauges may be obtained by which to grind forged tools for the different pitches.

105. Spiral Gears. The angle of a spiral gear is the difference in direction between one of its teeth and the tooth of a plain spur gear. In calculating the size of the blank the **spiral circular pitch** must be found. This is the distance from center to center of two adjacent teeth measured on the side of the gear, and therefore obliquely to the line of the teeth. The **normal pitch** is measured at right angles to the line of the teeth, as in the case of spur gears, and corresponds to the circular pitch of the latter. To obtain the spiral circular pitch divide the normal pitch by the cosine of the angle of the spiral, or

$$\text{Spiral circular pitch} = \frac{\text{normal pitch}}{\text{Cosine angle of spiral}}.$$

Having the spiral circular pitch we use it to obtain the circumference of the pitch circle, as in the case of the circular pitch of a spur gear; that is, multiply it by the number of teeth. Find the diameter of the pitch circle as in the case of the spur gear; add two addenda and we have the size of the blank. The depth of the cut is found as before.

The method of setting the milling machine for spiral cutting was explained in Chapter XII.

QUESTIONS ON GEARING

1. What is meant by diametral pitch?

2. What is meant by circular pitch?

3. Assume that a template is desired for gear teeth, 3 diametral pitch and 15 teeth. Calculate the size of the wheel. Draw to some convenient scale, showing pitch, diameter, whole diameter, thickness of tooth, depth of tooth, and how you determine clearance.

4. In cutting this same wheel, or template outline, what index circle and how many holes should be used?

5. Distinguish between miter gears and bevel gears.

6. Draw an outline of a pair of bevel gears, running at 90°, indicating pitch diameter, face of tooth, thickness of tooth, and cutting angle.

7. Calculate the size of a pair of bevel gears: 32 teeth $5P$, 44 teeth $5P$.

8. State the principal reason why the cutting, by a rotary cutter, of a bevel gear gives only an approximation. Why is it not accurate?

9. How is the pitch of a worm usually given?

10. What is the angle of pressure on a worm?

11. How does it correspond to a rack tooth?

12. Calculate the size of a worm wheel to run with a worm $2\frac{1}{2}''$ diameter, three threads per inch (single), 30 teeth.

13. What is a hob?

14. How much larger must a hob be than a worm?

15. Calculate the size and all dimensions for rack teeth for $1\frac{1}{2}''$ pitch.

16. Make an ink sketch to scale of the same.

CHAPTER XV

GRINDING

Materials for grinding. Abrasives and the order of their cutting efficiency. Grain and Grade. Rules to be followed in mounting wheels, and why. Safe speeds. What limits the speed. Value of balance. How to increase speeds. Table of speeds. Different types of machines and their uses.

106. Abrasives. Every boy has experienced at one time or another the value of abrasives, without thinking much as to the theory. When the hands were stained with pitch pine or resin, or other substances that would not yield to the ordinary washing soap, a handful of sand has proven the means of accomplishing results, and it was because the sand acted as an abrasive and *cut* the dirt off.

For shop use, in sharpening tools, and for manufacturing purposes, abrasive materials in the form of wheels of various shapes are of increasing importance. The ordinary **sand grindstone** found in every shop is an abrasive wheel of the softer variety. This is a natural stone.

Other substances, when made into artificial wheels, are of much greater value to the manufacturer. These are: **emery**, which is harder than sandstone; **corundum,** which is harder than emery; **carborundum,** which is one of the hardest of all, only exceeded in hardness by the diamond, the dust of which is commonly used as an abrasive by jewelers. **Alundum** is still another abrasive of reputation which combines hardness, temper and sharpness; it and carborundum are electric furnace products, fused at about 3000° F.

These abrasives are ground into various size grains,

and are sorted by being passed through sieves of varying mesh. These sizes are designated according to the number of threads or wires per linear inch of mesh; for instance, those grains which pass through a sieve with 100 threads or wires per linear inch are known as No. 100. Similarly grains numbered 90, 80, 70, 60, 50, 40, 30, etc., are those which pass through sieves of corresponding mesh. These numbers show the abrasive wheel's coarseness or fineness, as the case may be, but have nothing whatever to do with the *grade;* this means the degree of hardness of the wheel.

By **grain**, therefore, is meant the size of the cutting particle, while by the **grade** is meant the temper of the grain, whether soft or hard. A wheel that wears away rapidly is called soft, and vice versa.

107. Method of Manufacture. The method of manufacture of these artificial wheels is as follows: Grains of one size are mixed together with a bonding material which is in itself an abrasive after it has become vitrified or baked. While this mixture is in a plastic state it is poured into molds and placed in drying ovens for a short time. After this drying period the wheels are brought to the desired size on special machines, and again dried out. They are then placed in ovens which are hermetically sealed and for a period of about 12 to 14 days, according to the size of the kiln, are subjected to varying degrees of heat, the highest being about 3000° F. This intense heat fuses the bonding material and vitrifies it, and at the same time tempers the grain of the abrasive. The wheels are then thoroughly inspected, and are tested at about double the commercial speed.

108. Use. Many conditions enter into the use of abrasives. First, the materials to be ground differ; we have iron,—cast, wrought or malleable; brass, bronze, alloys of any kind; steel of hard or soft quality. Each of these needs different treatment. The amount of metal to be removed, whether a roughing cut or only a few thou-

sandths for finish, the nature of the finish, and whether ground wet or dry,—all of these conditions must be considered, and the grain and grade of the abrasive wheel and its speeds and feeds made to conform. In this it is well to get the advice of men who have made a special study of the problem.

Different manufacturers of wheels have different methods of designating the grades of their product. The Norton Company, of Worcester, Mass., designates the degree of hardness or grade of its alundum wheels alphabetically, in a sort of alphabetical progression, from *soft* to *hard*. Carborundum wheels are designated in just the reverse manner, *hard* being indicated by the beginning of the alphabet and *soft* by the letters toward the end.

As before stated, conditions vary so much that no absolute rule can be laid down for selecting wheels of proper grade and grain for any specified material or work, but the following short table will be an aid in making a choice:

	Grain.	Grade.
Iron and steel castings	12 to 25	Q to U
Malleable castings	14 to 20	P to R
Chilled iron castings	20 to 30	O to U
Wrought iron forgings	12 to 30	P to U
General machine shop use	24 to 46	O to P
Small tools	36 to 100	N to P
Reamers, milling cutters, etc.	46 to 100	J to M
Wet tool grinding	46	J

109. Fundamentals of Grinding. Grinding is a cutting process, each particle of abrasive being a cutting tool, with a well defined cutting edge or point, and, therefore, we have, in a grinding wheel, a *multiple-tooth cutter* with an almost infinite number of teeth. To get the highest efficiency from any multiple-tooth cutter, each tooth must have a chance to do its share of the work; this means that the abrasive wheel must run true. Hence, in mount-

ing a wheel the first essential, after it is properly mounted, is to true the wheel by a thoroughly reliable mechanical method. Do not try to hold a diamond tool or an emery wheel dresser in your hand, in truing a wheel, but have it rigidly fixed in a suitable tool post and, by means of the table or platen, feed it across the face of the wheel. It is advisable to have the wheel rotated by hand at a nominal speed, rather than run at its cutting speed, while the process of truing is going on; the particles will not be burned or fused.

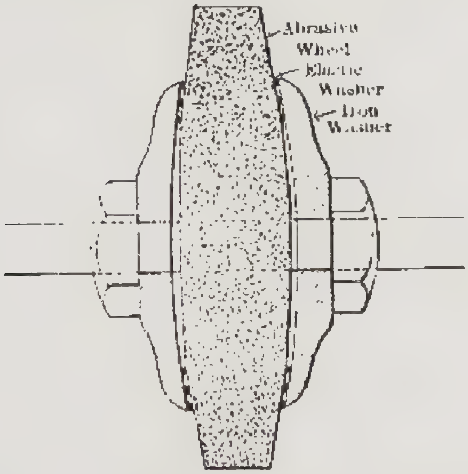


FIG. 146

Again let the student remember that no mechanic can do good work on any machine unless he is thoroughly familiar with the conditions under which the machine operates at its highest efficiency; this is true of grinding materials as well as of others. He should know that the wheel has not been forced on the arbor, but fits freely, yet without play. He should know that it has been properly cushioned under the washers to absorb shock, heavy paper (not hard) or thin rubber being used. The washers should be large enough to hold firmly, covering a large area of the side of the wheel. They should be at least one-half

the diameter of the wheel, preferably larger; if the nature of the work to be done will allow it, they may be two-thirds the diameter. The washers should fit on their outer edges as in Fig. 146.

We are enabled to run grinding wheels at an extremely high speed, due to the many cutting edges, but in speed lies the greatest danger. Hence, the operator should make sure that the speed at which the machine is belted is within the safety zone. A speed indicator is a necessary tool. The safe working speed should not exceed 5000 feet per minute. Wherever it is possible the wheel should be

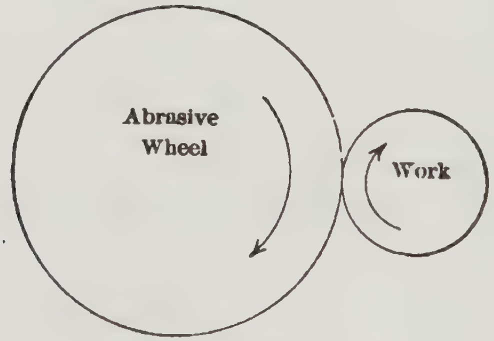


FIG. 147.

covered with guards or hoods as a safety measure in case of breakage.

It is essential that the direction of rotation of both wheel and work be correct; many mechanics have failed on this particular point who were well informed on other essentials. The work and the abrasive wheel must pass each other *in opposite directions*, as in Fig. 147.

110. Grinding Machines. For many years most shops have been equipped with machines for sharpening tools, ranging from the wet and dry grinders for lathe and other tools to those for sharpening reamers, milling cutters, etc. Only within comparatively recent years has the grinding machine taken its place as a manufacturing tool. In

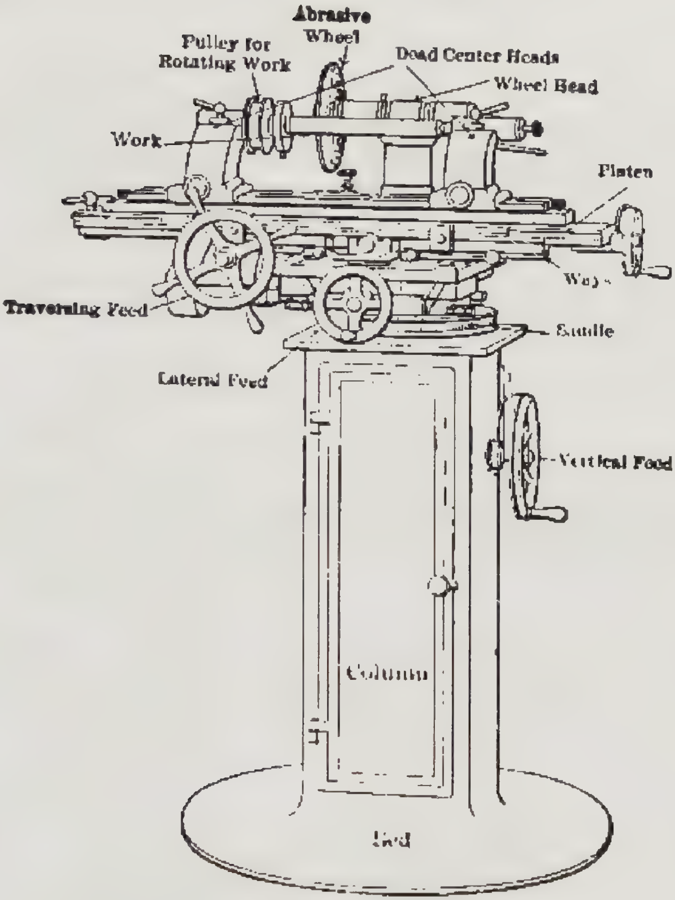


FIG. 148.—Norton Tool Grinder.

Bed (C. I.)	Column (C. I.)	Saddle (C. I.)	Platen or table (C. I.)	Head stock (C. I.)	Driving pulley (C. I.)	Work
				Tool Stock (C. I.)	Centers (T. S.)	
				Traversing mechanism (Cru. steel)		
			Lateral feed (Cru. steel)			
			Traversing feed (Cru. steel)			
		Abrasive wheel head (C. I.)	Spindle (Cru. steel)	Wheel		

certain work, such as agricultural machinery, it has been found economical to use the grinder. Upon work of a higher grade, such as many automobile parts, the finish-

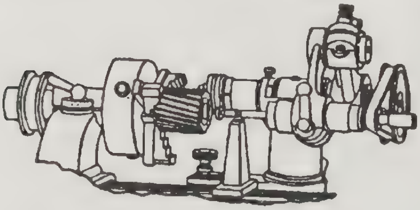


Fig. 149.—Method of Using the Internal Grinding Attachment, Ready to Grind.

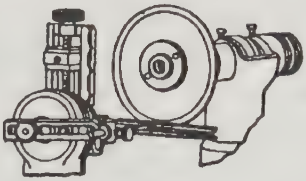


Fig. 152.—Grinding Flutes in Taps.

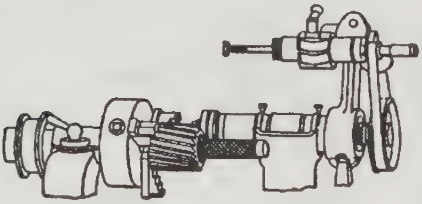


Fig. 150.—Internal Grinding Attachment, Thrown out of Position for Purpose of Measuring Work.

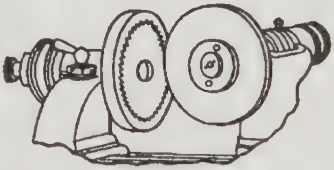


Fig. 153.—Method of Holding Saws and very thin Work by Means of Expansion Spindle.

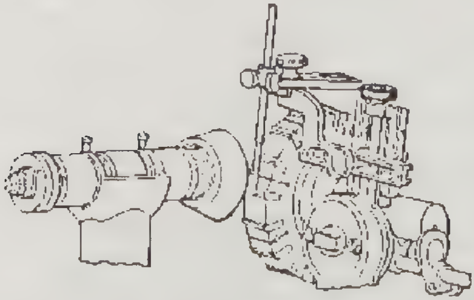


Fig. 151.—Cup when Used to Grind Inserted with Cutters.

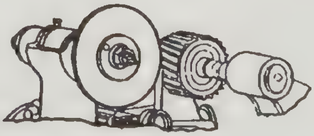


Fig. 154.—Grinding Spiral Mill Showing Finger Stop.

ing is done by grinding. Much of this development is doubtless due to the improved abrasives now used and to the advance in the art of wheel making. Special wheels

and special machines are used where warranted by the large number of identical parts produced.

In Fig. 148 is shown a machine suitable for sharpening milling cutters and for finishing centers, mandrels, and other light work. Figs. 149 to 154 illustrate some of the work which can be done on this machine. In Fig. 155 is shown a much larger and heavier machine adapted to manufacturing.

These machines by no means exhaust the list or show all the types. The heavier, coarser work is done on plain grinders, as a rule, rather than on universal machines. There are machines adapted to cylindrical work only, while others are for surfacing.

Grinders are especially built for sharpening twist drills. There are obtainable, also, attachments for grinding work in the lathe; this includes both outside and inside grinding. A variety of small, portable, electric grinders are now made; these often prove valuable adjuncts to the usual shop equipment.

QUESTIONS ON GRINDING

1. In mounting an abrasive wheel, what precautions are necessary?

2. How is the jar on an abrasive wheel taken care of?

3. What is the first thing to do after mounting a wheel?

4. What is the advantage of truing a wheel by hand?

5. What is the result on the work
   (*a*) When the wheel is too soft?
   (*b*) When too hard?

6. About what speed is safe for the general run of abrasive wheels used in the shops?

7. What is the advantage of speed in cutting?

8. How are wheels graded? Give general information as to grading of grain, etc.

9. Why is there a limit to the speed of an abrasive wheel?

10. By what means can this speed be increased and still retain a factor of safety to the operator?

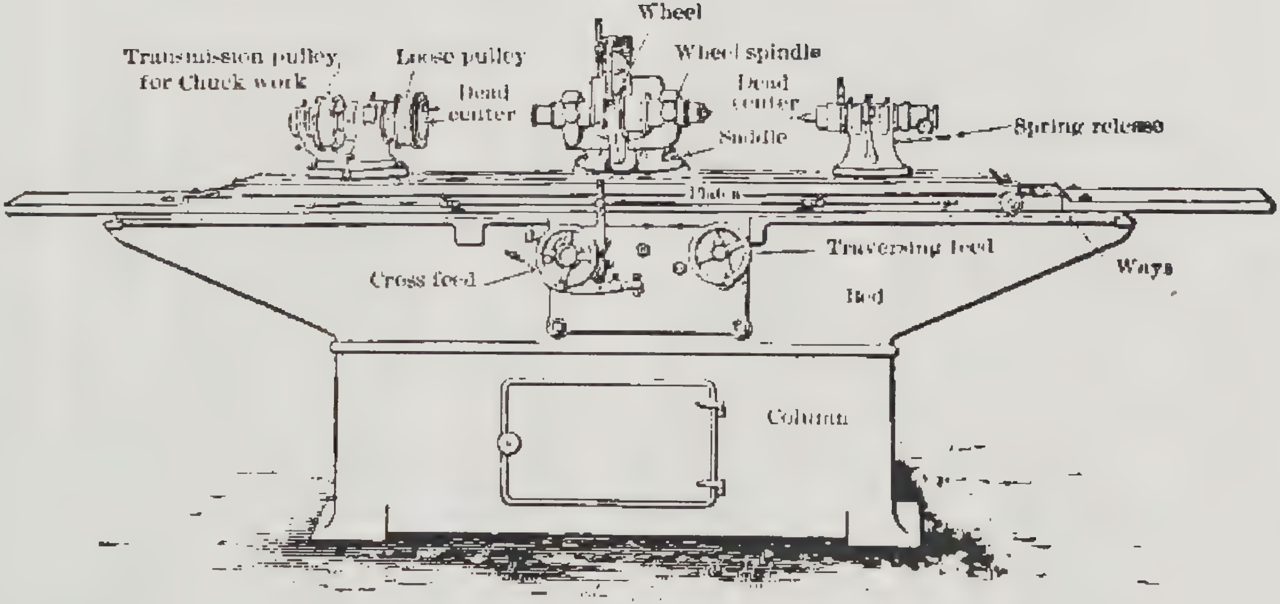


Fig. 155.—Heavy Grinder for Manufacturing.

Column (C. I.) | Bed (C. I.) | Platen (C. I.) | Saddle (C. I.) | Abrasive wheel head | Wheel
Two heads | Centers
Traversing feed mechanism (C. steel)
Cross-feed mechanism (C. steel)
Transmission gears (C. I.)

11. Give grain and grade of wheels for grinding tool steel, cast iron and bronze.

12. Make a sketch of a wheel and show a method of mounting that will prevent the wheel from flying out, if broken.

13. What is emery? Corundum? Carborundum?

14. Which is most efficient? Why?

15. What speed (surface) is safe practice for an emery wheel, wet? Dry?

16. What speed for leather-covered wheels?

17. What is the disadvantage in not having proper feeds?

18. What is the most important thing to do before grinding work?

19. What element of danger is to be safeguarded against? What are some of the methods you would consider in avoiding that danger?

20. How are carborundum and emery graded?

21. What letter indicates hard? Soft?

22. What is a good grade for cast iron? What is a good grade for soft steel? What is a good grade for hard steel?

23. What is the advantage of grinding work on dead centers?

CHAPTER XVI

TOOL STEEL

Carbon and high-speed steels. Different kinds of steel and their properties. High-speed steel efficiency. Annealing, forging, hardening and tempering. Cracking. Warping. Strains. Pack hardening.

111. Tool and Mild Steels. Steel is an alloy of iron. It is commercially pure iron, combined with certain other elements such as carbon, tungsten, manganese, chromium, nickel, etc. The proportion of these elements naturally determines the character of the steel. The student should know the two general grades of steel: *tool steel* and *mild steel*,—the latter often referred to as "Bessemer" or as "machinery" steel.

Tool steel differs from mild steel in its content of the various hardening elements named; it is a "high carbon" steel.

Mild steel differs from wrought iron in that it is free from slag; it entered the engineering field when the Bessemer and open-hearth processes introduced the new class of iron which to-day is called mild or "low carbon" steel.

112. The Manufacture of Tool Steel. The steps by which we derive the higher grade of tool steel from the iron ore are, briefly traced, as follows: The ore is mined, and from it the iron is extracted by the process of *smelting* at a high temperature in *blast furnaces*, from which it is tapped or poured into molds, forming "pigs." The iron in these pigs is impure, to the extent of from 5 to 10 per cent of phosphorous, sulphur, silicon, etc.

From this pig iron, by a process of *puddling*, wrought

iron is produced; the puddling is in furnaces where the pigs are melted in contact with diluted oxides, and stirred or robbled, in a pasty mass, until nearly all the impurities are oxidized or "burned out." From the puddling furnace the ball of molten metal, weighing about 75 lbs. or more, is put through the rolls and squeezed and rolled into bars, called "muck bars." There is still the element of impurity in these bars, and they are cut into small pieces and made into oblong "piles," which are reheated and rolled into "merchant bars."

The purest ores are used to make the wrought iron which is to be converted into tool steel. The wrought iron is rolled into certain adaptable shapes, about $\frac{3}{4} \times 3''$, cut up and placed in special boxes. The pieces are separated from each other and from the box by hardwood charcoal, the top layer being covered with it, and the box hermetically sealed with clay to exclude air. The whole is then subjected to a high temperature for a long period of time; about 2000° F. for seven to ten days. The iron absorbs carbon from the charcoal in which it is packed, and is converted into what is called "blister" steel, from its appearance when taken out of the packing. This is called the "cementation process." The tool steel thus obtained is not likely to be homogeneous or uniform in texture, and therefore is not altogether reliable, although it can be improved by forging and working.

The process of manufacturing crucible tool steel, as devised by Huntsman, is to break up the "blister" steel into small pieces, which are melted with certain fluxes in especially prepared clay crucibles. The heat is carried to a certain temperature, at which it is maintained for a definite period and the metal is then poured or teemed, at the proper moment, into moulds, forming ingots of "crucible" cast steel.

The method which is largely employed in the United States for making crucible steel eliminates the cementation

process. The wrought-iron bars are broken up and charged into graphite crucibles, from which the iron absorbs carbon together with other elements called "medicine," such as manganese, etc. This process produces a steel of uniform quality and reliability. The great value of any tool steel lies in its uniformity; that is, the whole bar and all bars of that grade should give the same results under the same treatment.

113. Fundamental Conditions for Tools. So many conditions must be considered and observed in the use of steel tools, as to make it practically impossible to fix a standard by which successful results will always obtain. In the first place, the grade of steel, as determined by its hardening content, should vary with the uses for which the tools are designed.

A tool which is to be subjected to constant shock, such as a cold chisel, should be of a different grade of steel from that employed to make a tool which is to be used under a constant load. In short, *one grade of steel is not adapted for all and every kind of tool.*

There are, however, certain conditions governing the manufacture of tools which are so fundamental that they cannot in any case be ignored. These are: first, a slow, thorough heating, to insure a uniform temperature throughout the whole piece; second, the temperature of the cooling liquid; third, the time and method of drawing the temper. Forced draught should not be used in heating tools for tempering, because of the too rapid expansion of the metal, as well as the resulting unevenness of the heat; the outside will be raised to the required temperature before the inside, and this will result in strains which may crack the tool. Expansion and contraction should be equal and uniform; too rapid heating by forced draught imposes a condition adverse to this.

114. High-speed Tool Steels. A distinction should be made between "self-hardening" and "high-speed" steel,

although they are commonly classified by the mechanic under the same heading. The student should note, however, that self-hardening steel hardens under the ordinary atmospheric temperature, during its cooling process, while the high-speed steels are all subjected to a more or less elaborate treatment to effect their speed-cutting properties.

It is a comparatively short time since the introduction of the strictly high-speed steels. The first really valuable experiments, one might say the first steps in this advance, were made by Mr. Frederick W. Taylor and Mr. Maunsel White at the plant of the Bethlehem Steel Works in 1898 to 1900, the actual results of which were publicly exhibited at Paris along with other makers' steels.

Each brand of high-speed steel has its separate, secret, chemical composition, and only generally do we know and speak of them as made up of varying quantities of tungsten, molybdenum, manganese, chromium, carbon, and the later ones of vanadium, for which still better results are claimed. As the percentage of these various alloys increases, the carbon element decreases; a large part of it combines with these elements at the high temperatures at which they are treated, forming carbides, which are very hard and are really the "cutting teeth."

It is a matter of record that, by the use of these steels, speeds have increased considerably, until frequently three or four times those for the ordinary carbon steels. The possibility of such increase in speeds may be accounted for, in a brief way, by saying that it is due to the different temperatures at which the two kinds of steel are treated. With both, the speed of the machine must be kept within such a limit that the temperature produced by the heat generated by the friction between the chip and tool, is kept below the temperature at which the tool was treated. As this treatment temperature ranges from 2000° to 2250° F. for high-speed steels, it is obvious that a greater speed is possible with these tools.

Fig. 156 shows a curve which was made at the time of the Taylor-White experiments by a Franklin Institute Committee, and shows clearly the action of temperature on both kinds of steel. The breaking-down point, or the temperature at which we would ordinarily destroy the efficiency, by burning, is 1550° F., for carbon steels, while the point is not yet reached at 1900° F. for the high-speed steels.

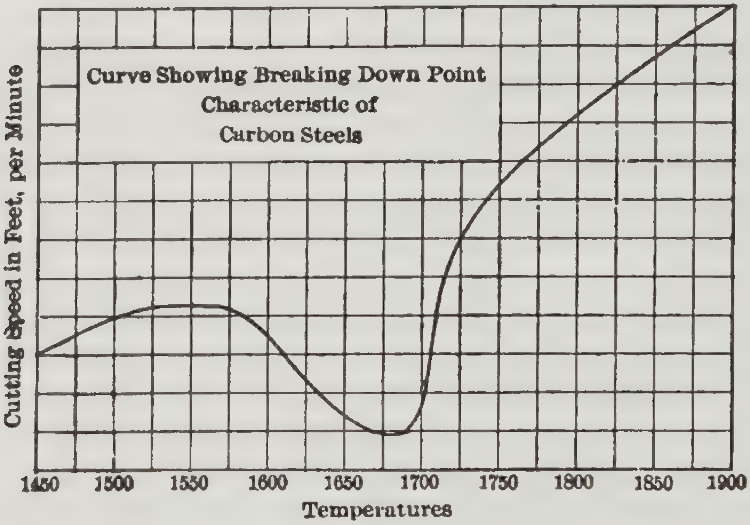


Fig. 156.

High-speed steel, as an economic factor, is revolutionizing modern manufacture, and, while it requires increased power to drive the machine tools, the returns from greater production much more than compensate for the cost of this increase. Heavier machines must be made, however, to meet the increased stresses which are placed upon the different parts, by the use of the new steels.

The treatment of tool steel may be classified under four heads: *Annealing, forging, hardening, tempering.*

115. Annealing. Steel is annealed by slowly cooling it from a low red heat. The longer the period of time elapsing in this cooling process, the more the strains that

have been set up by rolling or hammering will be eliminated. Primarily, annealing is for eliminating these strains, rather than for softening the steel. The softening of the steel is a by-product, as it were, of the heat treatment, which allows the carbon to separate and diffuse itself throughout the mass.

Most of the makers of tool steel to-day anneal their product before sending it out to the trade, whereas, in years gone by it was thought that to anneal a piece of tool steel was to injure it to a certain extent. Under the methods used this very often was true, because the steel was overheated, was cooled too quickly, or was allowed to cool in substances which tended to decarbonize it or to impart impurities to it.

Annealing improves the grain of steel, if properly performed. Cast-iron annealing boxes are now used to a great extent, in which the steel is packed in charcoal, ashes, or any other substance which retains the heat. These are sealed with fire clay, and a period of time, sufficient to allow the separate strains to adjust themselves, is given. In the early days lime was used, because of its heat-retaining qualities.

Some tool makers and steel workers have become very proficient in the quicker method called "water annealing," in which the steel is heated to a low red, and held either in a dark corner until all color disappears, or between dry pine boards until the steel fails to spark the wood, and is then quenched.

A safe method to observe in working tool steel, especially if the mechanic does not know his steel, is to first rough out the tool, and anneal it before finishing, and although this may take a little more time, the final results in hardening and tempering will more than compensate for this loss. Nearly every tool steel worker has experienced trouble at one time or another with steel containing hard spots due to improper annealing, these hard

spots being masses of combined carbon which was not affected by the annealing. The time of cooling is the factor which must not be ignored; it is really more important than temperature. There is very little excuse for finding these hard spots in steel to-day, with the advanced methods of conducting the annealing process in improved annealing furnaces, where temperatures can be regulated, if the time element is carefully observed.

116. Forging. By forging is meant the heating and hammering of the metal, by which it is made to assume a definite shape and size. In forging care must be exercised to secure the proper degree of heat, and the part of the bar being forged must be heated uniformly throughout, as already noted under the subject of annealing.

The degree of heat to be employed depends on the size and shape of the piece, upon the carbon content, or grade of the steel, and upon the use to which the finished product is to be adapted. Judgment must be used as to the force of the blows when hammering—good hard blows are to be struck if the piece is large, and gradually lighter ones as it becomes smaller and cooler.

A piece of steel will be improved by proper hammering, as the density of the grain is increased; such steel being commonly known as "hammer refined." If hammered when below a certain temperature, however, the grain is crushed and the steel is then injured.

The part that has been forged may be only a small part of the tool; if the rest of the steel has been left untouched, what is commonly called a *forging strain* is caused. This is due to different densities in the hammered and unhammered parts of the steel, and to relieve these strains the piece should be annealed after forging. It is a point worth our notice, that a cold chisel, a lathe tool, or even a screw driver, gives far better results, if, after forging, it be reheated and allowed to cool slowly before heating for the hardening and tempering.

117. Hardening. This may be considered under three distinct heads:

First, the nature and composition of the metal, that is, the grade of the steel.

Second, the temperature of quenching, or the refining heat, which depends almost wholly on the carbon content of the steel.

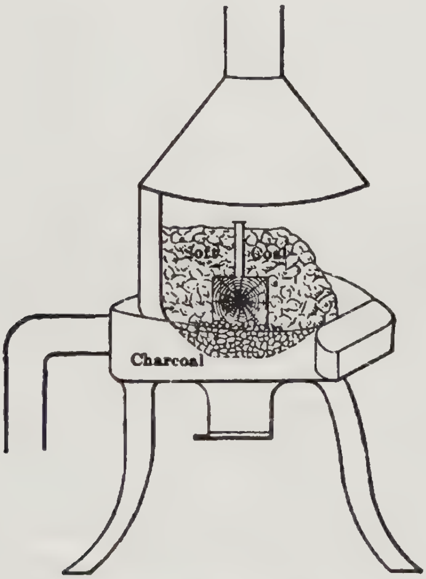


FIG. 157.—Hand Bellows Forge for Hardening.

Third, the nature, volume, and temperature of the bath which is determined from the piece to be hardened, its size, shape, and degree of hardness, or the use to which it is to be subjected.

In this advanced age it may seem rather elementary to give space to a discussion of ordinary methods in hardening tool steel, but so much depends upon a thorough knowledge of a few elementals that it may be wise to consider them in this particular place. Every toolmaker will not have modern conditions under which to work; nor is it the man who, given the best conditions, can always do

good work, that is so likely to succeed as the one who can create his own conditions and produce results.

Good results have been obtained even with soft coal, when no other facilities were to be had, although soft coal with its inherent sulphur is not ideal. Fig. 157 illustrates the ordinary hand bellows forge which has been prepared, or is being prepared, for tool steel hardening. The bottom of the forge has been cleaned out, and a handful of pine shavings or waste put in, upon which a quantity of charcoal is placed. Upon this a block of wood is placed, the size depending upon the size and shape of the tools to be hardened. A piece of gas pipe is set upon this block, in a vertical position as shown, for a vent. Over the block and around the pipe is packed the soft coal, which has been crushed and thoroughly wet down to insure solidity in packing. The fire, which is started in the shavings and waste underneath, is transmitted to the charcoal, and very little draught is needed to keep this burning. When the block of wood has been consumed, the soft coal has been coked, and a sort of muffler, the size of the block, has been formed, which will give very satisfactory heating conditions for small tools. It has certain muffler qualities, such as heat-retaining walls, and needs very little draught to keep it going. This matter of draught is important; if it were not so, the muffler might never have been brought into use, to avoid the air coming in contact with the steel. Forced draught, as before stated, should be avoided when you are compelled to use a forge. A slow heating allows for normal expansion and gives us the right to expect normal contraction when the piece is cooled. Again, the outside of the steel should not be brought to the refining heat before the center is heated to the same degree.

With respect to refining heat, every different temper of tool steel (speaking now of the manufacturer's term temper) has a different refining heat. To determine what

this is in any case, take a piece of the steel 6″ or 8″ long and $\frac{1}{2}$″ to $\frac{5}{8}$″ in diameter and, with a file or tool, nick it every $\frac{3}{4}$″ or so, and heat it so that one end will be near the melting point. Then let the heat slowly run toward the other end, from the white or melting heat at one end to the black heat at the other, and quench it. After drying, break off the nicked sections, starting at the end which had the highest heat. This overheated end will break very easily, and will show a coarse grain, as indicated in Fig. 158. The force needed to break off the sections will increase as the black end of the steel is approached, but some one section will show a very fine grain, which indicates

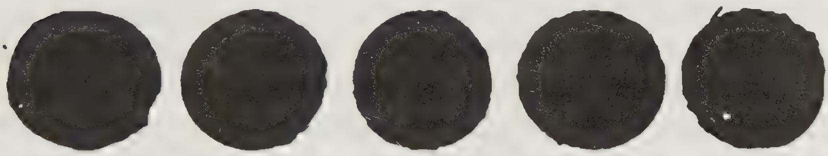


Fig. 158.—Grain of a Rod which has been Hardened.

that here the refining heat was reached. As the end is neared, there is a tendency to bend before breaking, and the grain will be found coarse until we reach the natural grain.

It is plain from this that overheating the steel opens the grain, which will remain open until the steel is allowed to cool and is again reheated to a refining heat. If by any chance, a tool has become overheated in hardening, it is well to allow it to cool slowly, and then to reheat it to the correct temperature and quench.

This question of refining is important, which is only another way of saying again that the worker must know his steel, so that he may avoid ruining a 1.6 per cent carbon steel, for example, by subjecting it to a heat suitable for a .75 per cent steel. To avoid to a great extent the chances of error, where several grades of steel are in daily use, it would be well to mark the various grades with

next to it into steam; this passes out into the body of the water and the next layer is, in turn, evaporated into steam, and so on, until all the heat is carried from the heated piece. When the heat is excessive, very often bubbles are formed which prevent the next layer of water from wholly surrounding the tool, and soft spots in the hardened piece are the result.

The more rapidly the heat is conducted from the steel by the hardening bath, the harder the steel will be. The size of the bath is also important, as too small a receptacle means a quick change in the temperature of the liquid, which would defeat the desired results.

The cooling bath should be agitated; that is, if water is used it should be running water, and if this is not at hand, the water in the receptacle should be stirred or whirled around and the tool or piece to be hardened should be dipped in the vortex or center of this whirling bath, to insure uniform extraction of the heat. Salts and acids increase the heat-conducting power of water. Common salt is mostly used—all that the water will dissolve.

Oils and fats are used to a great extent as hardening solutions, because they tend to make the steel less brittle than does water. They have less hardening power, but give the steel a toughness that water will not give. Neat's foot, lard, or fish oil, may be used, and will be found satisfactory for small tools, springs, etc. This characteristic of the oil bath explains why it is frequently used as a second bath for tools, having projecting edges, such as reamers, end mills, spiral cutters, etc. The teeth need to be hard for about $\frac{1}{3}$ to $\frac{2}{3}$ their depth, and the tool is first dipped in water or brine for a short period of time, and then plunged in oil, and allowed to cool there. This serves a double purpose,—that of giving the necessary hardness to the cutting edges of the teeth from the water chill, while retaining a desirable toughness at the base. Some tool makers use oil in a combined hardening and tempering process.

It is better, however, to differentiate between the two processes, first hardening the tool and afterward tempering it.

A very common method is to use the water bath with oil on top, when the piece requires hardness but is liable to crack under the shock of sudden cooling. The oil through which the tool has to pass diffuses itself over the whole piece and prevents that sudden contraction which water alone would produce.

As to the time of cooling, a safe rule to observe would be to time the vibrations or hissing; when all vibration or hissing ceases, the tool is as hard as it can be made, no matter how long it is held in the bath.

Among other hardening agents there may be mentioned mercury; its excessive cost and the dangerous fumes arising from it put it in a special class of such agents. Small dental tools are frequently cooled by the use of a mercury bath. For very small drills, where extreme hardness is required, a potato will prove the best hardening agent, about 90 per cent of it being water and the other 10 per cent starch; of the starch, about 40 to 50 per cent is carbon. Sealing wax will prove a very good substitute for the potato for small drills and fine-point tools of extreme hardness. Cold lead, a block of which is found around every machine shop, has been used with excellent results for flat drills, which, after heating, are driven down into the lead.

When many pieces of a kind are to be hardened, the process known as *pack hardening* is extensively used. The pieces are packed in an iron box and surrounded with charred leather, bone dust, hoof parings, etc. The value of this method is not only that a large number of parts can be treated, but that they will be alike as to hardness, due to the possibility of an even temperature throughout.

122. Tempering. Hardening and tempering are too often confounded and used as identical terms. Hardening drives the heat out. Tempering is accomplished by putting

heat in. When the tool steel has been hardened, it is left very brittle and is not usable until some of that brittleness has been removed and the metal toughened, or, as we say, tempered.

A piece of tool steel which has been made hard will, if dried, polished, and held over a Bunsen flame, be affected by oxidation. A thin film of iron oxide will coat the whole piece and show different colors according to the different temperatures to which it is raised, from the light straw for reamers, taps, etc., down through the dark blues for cold chisels, to the greenish gray of the natural temper. At 412° F. the first change begins to take place; that is, the hardened piece of steel must be raised to 412° before any change is possible; from that degree up, the changes vary with the temperatures.

The color scale of temperatures, handed down to us from our forefathers, was long the standard for drawing the temper in tools for different uses, but it is rather of approximate than of real value, because the difference in carbon content gives different colors for fixed temperatures. This color scale is shown in the following table:

432° F. LIGHT STRAW.	Metal working tools for planer, lathe, etc. All tools for hard substances, such as ivory, bone, etc.
450° F. NATURAL STRAW.	All toothed cutters, such as milling cutters, reamers, end mills, taps, etc.
470° F. DARK STRAW.	Punches and dies. Wood bits. Tools for stone and marble.
490° F. BROWN.	Wood-working tools generally. Ordinary temper for drills.
520° F. BRONZE.	Saws. Springs. Small instruments.

550° F.	Purple.	Screw drivers. Wood chisels and gouges. Cold chisels for metals.
570° F.	Blue.	Wood saws and those tools on which it is desired to put edges with files.
600° F.	Dark Blue.	Easily filed.
632° F.	Greenish Gray.	Natural temper.

In our present-day methods, tempering is not based upon the guessing of these colors, as most of it is done in specially prepared tempering baths which are equipped with thermometers. Heavy oil, heated to the required temperature, is used mostly in these baths. It is obvious that the length of time does not figure in the drawing of the temper in such a bath, because after the heat has once reached all parts of the hardened tool, it is the same temperature as the oil and cannot become any hotter.

Hot sand is used for drawing small pieces in quantity. Long, thin pieces are sometimes tempered in tubes or sections of gas pipe which have been heated, and which give a uniform heat to all parts of the piece.

123. Methods of Dipping. The proper way to insert the piece in the bath must be learned by one who is working tool steel. Certain results are demanded; besides obtaining the right temper, the shape of the piece must be kept unchanged. The most important factors to consider are the expansion and contraction of the metal with the changes in temperature. As an illustration, suppose a reamer, 7″ or 8″ long, after heating is plunged in the bath flat, so that one side, along the entire length, first comes in contact with the cooling liquid; the piece will immediately contract on this side, while the other part is still expanded up to the point at which it feels the chill. There is little question as to the shape it will have when taken from the bath,—a curved shank rather than a straight one. Again,

take a wedge of any kind, a large knife blade for instance, and dip it edge first, which sets the grain of the edge. When the large area of the back begins to set, it pulls the thin edge whither it wills and leaves anything but a straight edge.

124. Summary. In a summary of the treatment of tool steel it is necessary to recognize:

The importance of strain due to unequal stresses;

The value of annealing;

That time, rather than temperature, is *the* factor in annealing;

That the annealing heat is a low heat;

That the refining heat should be gradually and slowly approached, to allow a thorough and uniform heating of the steel;

That the tempering bath should be of the right temperature and according to the prospective use of the tool;

That a combination of oil and water gives a tougher structure to the steel than water alone will give;

That, in tempering, the degree of heat should be regulated according to the grade of steel used;

That the part of the work having the largest area should be dipped first, and in a vertical position;

That the hardening bath should be agitated.

QUESTIONS ON TOOL STEEL

1. What are some of the precautions necessary in handling tool steel preparatory to working it to size?

2. Why do you anneal the piece after roughing?

3. How do you overcome hard spots in tool steel?

4. In annealing tool steel, how does the temperature compare with the hardening temperature? Is it higher or lower?

5. How should steel be heated for hardening? What care should be exercised?

6. Give method of hardening to obtain a tough, uniform temper; give reasons underlying each step.

7. How should tools be dipped, what precautions should prevail, and what is the result if precautions are not taken?

8. Give the color scale of temperatures for tempering different tools.

9. What is the difference between hardening and tempering?

10. What is a " muffle " furnace?

11. What is a " muffle " used for?

12. Why is oil used in hardening and tempering?

13. What is the effect of forced draft in a fire in which you are heating tool steel?

14. Why is a fire made of soft coal to be avoided?

15. What effect has charcoal fire on steel?

16. What is the proper way of heating steel for hardening?

17. In hardening, what are some of the essential things to be considered?

18. Give different baths for hardening in common use in practice?

19. What is carbon steel?

20. What is the difference between carbon steel and superheated steel?

21. What advantage has superheated steel over ordinary carbon steel?

22. What gives superheated steel its efficiency?

APPENDIX

SYSTEM

Method of keeping track of work through the various departments. Time, stock and repair cards. Construction chart. Construction sheet and its uses. Job order cards and how used. Their value from an economic standpoint.

Numbering Systems. In any numbering system it is important that proper emphasis be laid upon the fixing of the number used. The problem presents three distinct phases for solution:

1. The main number must never be duplicated.
2. The method of assigning this number must be simple.
3. Certain figures in the number should have the same meaning in all departments, and unlimited expansion should be possible to cover details without altering the main number.

The reason for the first of these propositions seems self-evident. Concerning the second it may be said that any instructor, after he has given a title to the work he wants done or the machine he wants made, must be able, by simply glancing at his numbering chart, to write down the main number of the job.

Subdivisions are necessary because in the shops we wish to keep track of the time, etc., on certain parts of the job assigned to one or a group of students; while uniformity in numbering subdivisions, and the possibility of expansion are necessary in the drawing-room and for foundry patterns, because every single detail of the job may require a distinctive number.

There are many complicated systems of accounting for

time, stock, material undergoing construction, etc., which do not lend themselves to smaller shops or organizations. The following system for a school shop has been devised and tried out by the author with very satisfactory results. The main features of the system will be apparent from the following discussion.

The job number stands for one job as a whole, no matter whether the work takes two hours or five years to complete. This number must not be duplicated, and the time and cost of every detail of the job, when finished, is charged to this main number. It is this job number alone that departments, other than construction departments, use to trace their work.

Emergency Job Number. All emergency jobs have the prefix X placed before the main number, as X529, X7986.

Determining the Job Number. The first and second figures of the job number are fixed for each department of the school for which the shop does work. The first figure indicates the department; the second figure indicates a definite class of work for that department, except in the "Miscellaneous" or 900 class. This second figure indicates, as in the five cases given below, the same general class of work in all departments.

Department Number.	Class Number.
000 Chemistry	00
100 Physics	10 Transmission equipment
200 Strength of materials	20 Exercises
300 Electrical laboratory	30 Exercises
400 Steam laboratory	40 New equipment
500 Machine shop	50
600 Foundry	60
700 Pattern shop	70
800 Forge shop	80
900 Miscellaneous	90 Repairs

For example, 4 is the number of the Steam Laboratory Department; hence every job number originating there will have 4 for the first figure. If the job comes properly under the head of new equipment the second figure of the job number will be 4, because new equipment is numbered 4 in all departments. In the case of large institutions, job numbers may be given four figures as already suggested; this would give three figures to class numbers or subdivisions.

The five class numbers unassigned in the table are to be assigned, as occasion arises, by the heads of the various departments, but when once assigned are not to be changed.

Class Subdivisions. A suggestion as to what is covered by the class headings in the table is as follows:

10. *Transmission Equipment.* 1. All hangers, brackets, shafting, couplings, pulleys, clutches, gearing, etc., which aid in transmitting the motive power from engine or dynamo to machine.

20, 30. *Exercises.* Work, in any department, which is used simply for the elementary instruction of the students, not as construction or project work.

40. *New Equipment.* Important instruments or machines which will last ten years or more. This is possible of further subdivision, as in the case of "Exercises," by using one of the free numbers.

90. *Repairs.* Any repair or break-down job to existing equipment other than transmission equipment.

Detail Numbers. In the drawing rooms and shops a figure will often appear to the right of the decimal point of the job number, and sometimes a figure and a letter, as 528.4, 528.45C.

Determining Detail Numbers for Jobs. Additional figures may be placed at the right of the decimal point in the job number, to be used in subdividing the work on any job. The first figure should be given as nearly as possible in accordance with the following general classification:

.0 Used to designate the assembly drawing.
.1 Wrenches, vises, small equipment.
.2 Plates, washers, etc.
.3 Stationary constructive part.
.4 Movable constructive part.
.5 Stationary motive part.
.6 Movable motive part.
.7 Pulleys, gears, etc.
.8 Fluid transmission.
.9 Miscellaneous.

In the example just noted, if the job is a detail of new equipment for the Steam Laboratory, such as the belt pulley of an engine, the figure at the right of the decimal point, in the job number, will be 7, the whole number being 440.7.

Further numbers may be added at the right of this detail figure, in sequence, at the option of the department concerned.

Detail Letters. To designate any detail of this main subdivision, the letters A, B. C, etc., may be used, referring to the drawing of the detail of said part on the detail sheet. The assignment of these letters is left to the discretion of the instructor of drawing.

It is suggested that the use of the letters be confined mainly to the drawing room, and to the numbering of individual patterns, while in other shops, the number covering the main subdivision of the job be given, and the name of the particular detail piece be written out.

To Determine the Numbers in the Miscellaneous or 900 Class. The figure next to the 9 is that of the department which is to do the work. The subsequent figure or figures preceding the decimal point may be assigned consecutively; or the third figure may be a class figure, in accordance with the classification given below, with the consecutive numbering following this. The choice of

these two methods is optional with the department concerned in doing the work.

Classification for 900 Class.

9–00 Models.
9–10 Jobs belonging to students.
9–20 Jobs of persons not connected with the institution.
9–30
9–40
9–50 Buildings and grounds.
9–60
9–70 Art department.
9–80 Engineer's department.
9–90

Note. Substitute for the dash the number of the department which does the work.

Detail numbers may be placed at the right of the decimal in accordance with the regular system.

Procedure in Assigning Job Numbers. The head of any department is responsible for assigning the number to the jobs of his own department. He determines the title and number of the job and sets these down first on a "job number chart," kept in a conspicuous place in his office. After the number and the title have been duly entered on said chart, they are placed on sketches for the drawing room, or on emergency tickets and sketches for the shops.

When any work in the way of equipment, construction or repairs is to be done with student labor, two general classes of jobs will naturally present themselves: *Regular* jobs, which require considerable preparation in designing and drawing. *Emergency* jobs, which can be made thoroughly clear by simple sketches. The former have the necessary tracings and blue prints. The latter have

sketches, with sufficient data for the efficient execution of the work.

The instructor wishing drawings, tracings, or blue prints made presents to the head of the drawing department the necessary sketches and data.

Construction Tickets for Regular Jobs. When drawings are completed, *construction tickets*, printed on salmon cards, are made out in duplicate for each part to be constructed, and for each shop which will have work to do on said part; also one *cost card*, as directed under a subsequent heading. One set of the construction tickets are kept on file in the drawing office; the other tickets are distributed as needed, with all the necessary blue prints and bills of material, to the various shops. On the completion of the work, the tickets are returned to the drawing room office, so that the duplicates may be filled out, and the shop tickets are sent back to the department which performed the work.

Construction Tickets for Emergency Jobs. Interdepartment requests for construction or repair work which cannot be "done while you wait," i.e., completed within one day, but requiring not more than two class periods, nor employing more than two men, are filled out in duplicate by the instructor wishing the work done. He uses the consturction ticket form, on a buff card; sending one card to the drawing office for filing, and one to the shop which is to do the work, together with the necessary sketches or directions. On completion of the work, the shop ticket is sent to the drawing office, as in the case of regular construction tickets.

The *construction ticket* shows the following:

Name of the job; its number; shop in which the work is to be done.

Date: When wanted

Date: When the drawing or pattern is delivered.

Date: When the work is completed.

Part or operation wanted.

Number of pieces wanted.

Hours of labor.

Expense (sundries bought for this particular job).

Cost of stock.

Signature of instructor (which is virtually a receipt for the completed work).

These tickets, as already noted, are printed on salmon cards for regular jobs and on buff cards for emergency jobs.

Cost Cards. When the construction tickets are being made out for any regular job, one *cost card* shall be headed with the number and name of the job; the date of starting, the name of the person requesting it, and of the person who designed the work, are also entered. This is printed on a blue card and is kept on file, in front of the construction ticket to which it refers, and serves as an index for the same.

When the construction tickets are all in, on any particular job, the record of the cost card is completed. The service of this card is to sum up the total cost in hours of labor, expense and material for the whole job.

Once a year the *emergency construction tickets* should be tabulated, and where there are more than three of the same class, a cost card should be made out, summing up the data contained therein.

Construction Sheets. When the shop instructor receives a construction *ticket* for any job, he makes out a construction *sheet* giving the number and name of the job, and assigns the parts and operations to his students. This sheet is designed as a record sheet for the instructor, for the job in detail. The exact method of using this sheet necessarily varies in the different shops, according to the judgment of the instructors.

Time Cards. At the end of each class period every student fills out a *time card*, and deposits it in a box especially provided for it. On this ticket the student shows the number of the job on which he has been working, the

part, the number of hours spent on it, and the material used for it. From these cards the instructor obtains the data for the construction sheet.

When the job is finished, the instructor O. K.'s the construction sheet, sums up the data, and transfers the record to the *construction ticket.* This ticket is then sent, with the completed job, to the person requesting it, who, in accepting the work, signs the ticket and returns it, as a receipt for work done, to the shop instructor.

The illustrations, Figs. 161, 162, 163, 164, 165, for a tapping machine, No. 542, will clearly show the method of using the system, as they show a job being carried through the regular order. This is only intended as a simple system to show the simplest way of following up the various jobs as they go through the different shops. It is capable of expansion or modification to meet almost any need.

BLANK MANUFACTURING CO.
CONSTRUCTION NUMBER CHART

000 CHEMISTRY · 100 PHYSICS · 200 STRENGTH OF MATERIALS · 300 ELECTRICAL LABORATORY · 400 STEAM LABORATORY · 500 MACHINE SHOP · 600 FOUNDRY · 700 WOOD WORKING · 800 FORGE SHOP · 900 MISCELLANEOUS

542	Tapping Machine	227	Test pieces
.1	Base	.1	Tension
.2	Heads	.2	Compression
.3	Pulleys		
.4	Shafts	243	Cement Moulds
.5	Tools for same		
547	Mandrel Press		
.1	Base	352.6	Jig for Wall Ter-
.2	Spindle		minal
.3	Gears		
		790	Remodelling Pattern makers lathes.
1440	Flexible Coupling		
1441	Testing Tables	793	Wood lathe Centres

DEPARTMENT CLASS NUMBER		FIGURES PLACED AT THE RIGHT OF THE DECIMAL POINT INDICATE DETAIL		MISCELLANEOUS CLASS NUMBER	
00.		.0		9-00	MODELS
10.	TRANSMISSION EQUIPMENT	.1		9-10	
20.		.2		9-20	
30.		.3		9-30	
40.	NEW EQUIPMENT	.4		9-40	
50.		.5		9-50	BUILDINGS AND GROUNDS
60.		.6		9-60	
70.		.7		9-70	
80.		.8		9-80	ENGINEER'S DEPT.
90.	REPAIRS	.9		9-90	

FIG. 159.

DEPARTMENT
CONSTRUCTION TICKET

542 JOB NUMBER — Machine SHOP

JOB Tapping Machine

DATE DELIVERED Jan 6 COMPLETED Jan 11 WANTED Jan 13

NO. OF PIECES WANTED 1 INSPECTED BY A.O.K.

PART OR OPERATION WANTED Complete machine

HOURS LABOR @ 22	30	6	60
EXPENSE		2	75
COST OF STOCK		4	87
TOTAL	$	14	22

DEPARTMENT
COST CARD

542 JOB NUMBER — Dept. A. ORDERED BY

JOB Tapping Machine

STARTED Jan 7 COMPLETED Jan 11 WANTED

	CARDS	EXPENSE		LABOR		STOCK		TOTALS	
DRAWING ROOM		2	75	6	60	4	87	14	22
PATTERN SHOP									
FOUNDRY									
FORGE									
MACHINE									
OUTSIDE	on I.F.E.							6	32

DESIGNED BY G.E.H. TOTAL COST $20 54

DEPARTMENT
DRAWING ROOM CARD

542 JOB NUMBER — Dept. A ORDERED BY

JOB Tapping Machine

DATE STARTED Jan 3 COMPLETED Jan 6 HOURS 27

	PATTERN SHOP	FOUNDRY	FORGE SHOP	MACHINE SHOP
NUMBER OF SETS WANTED				1 ✓
DATE DRAWINGS DELIVERED				Jan 6
DATE WORK COMPLETED				Jan 11

FIG. 160.

Machine
SHOP

DEPARTMENT
CONSTRUCTION SHEET

542
JOB NUMBER

JOB Tapping Machine

ORDERED BY Department A

NO. OF PARTS	PARTS	WORKMAN OR CHECK #	DATE	TIME	MATERIAL				BEGUN	FINISH	TOTAL TIME
1	Base	#312									
1	Head Stock	#345									
1	Tail Stock	#387									
3	Pulleys	#302									
		#323									
		#349									
3	Shafts	#388									
		#303									
		#311									
	Tools for same										
	machine										
	Drill Jig	#321									
	Milling "	#329									
	Mandrels	#394									

APPROVED BY____________________

FIG. 161.

A DEPARTMENT

SEC. TIME CARD JOB NUMBER 542.1

JOB Tapping Machine

CHECK #340 FOREMAN

PART Base NO. OF PIECES 1

MATERIAL	OPERATION	TIME IN HOURS
C.I.	Planing	6½

REMARKS

TOTAL TIME 6½

DATE Jan 7 1911 INSTRUCTOR OR GEN'L FOREMAN

5108 5000 12-1-10

CHECK NO. 388 STOCK ORDER CARD A

PRESENT TO STOCK CLERK OR TOOL-ROOM ATTENDANT

PIECES	JOB NO.	MATERIAL
3	5424	Crucible Machine
		steel.
		7½ × 1" Dia

DATE Jan 7 1911 INSTRUCTOR OR FOREMAN

JOB NO. 599 DEPARTMENT

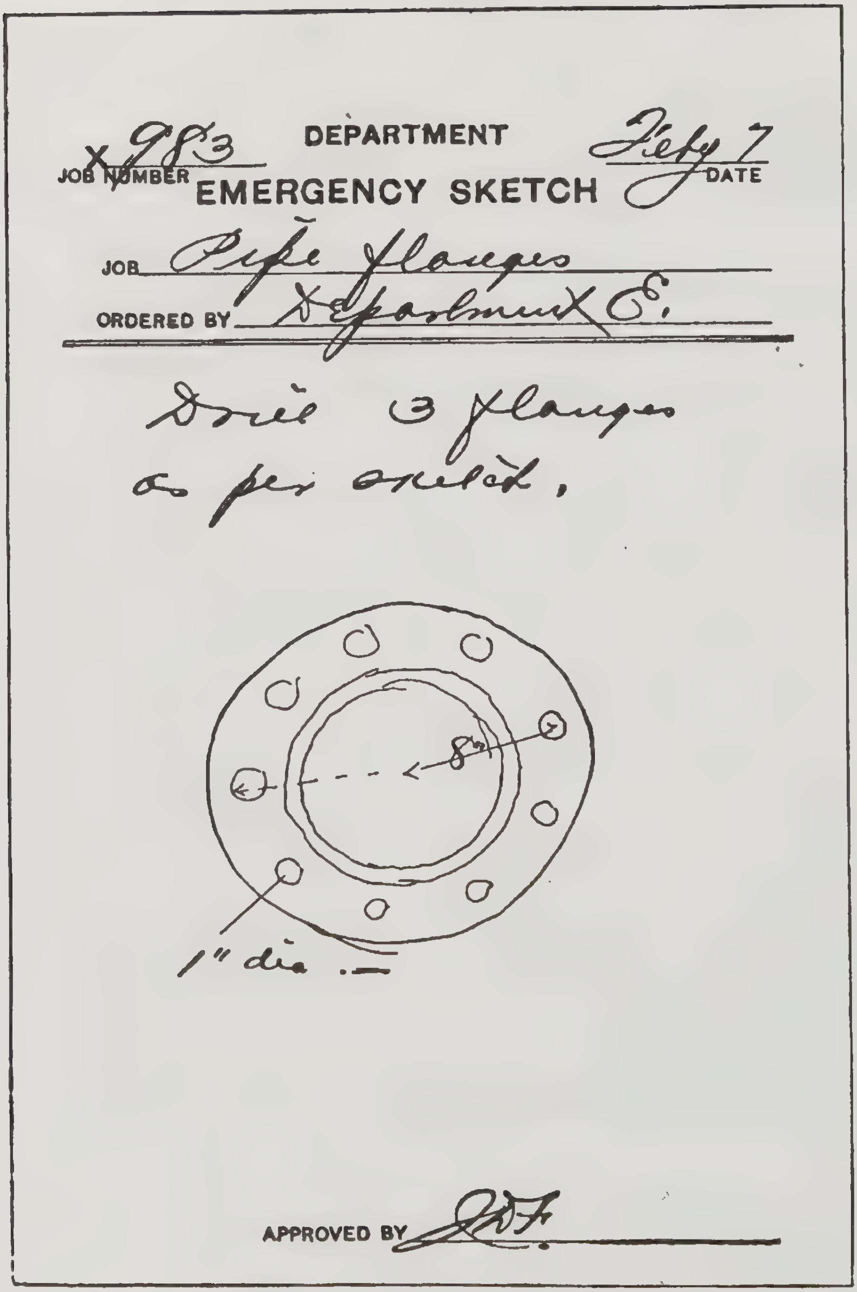
REPAIR ORDER CARD

RETURN TO HEAD OF DEPARTMENT WHEN WORK IS COMPLETED

MACHINE OR APPARATUS	DESCRIPTION OF REPAIRS
Countershaft on	Bush pulley
Lathe #11	& adjust clutch
	TIME 9¼ hr

DATE Jan 19 1911 (SIGNED) E.A.W.

Fig. 162.



x 983 DEPARTMENT Feby 7

JOB NUMBER EMERGENCY SKETCH DATE

JOB Pipe flanges

ORDERED BY Department E.

Drill 3 flanges
as per sketch.

8"

1" dia.

APPROVED BY

FIG. 163.

INDEX

En pining

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236011LV00005B/14/P

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